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Water Resource Challenges and Opportunities for the 21st Century

Proceedings of the First USDA Water Resource Research and Technology Transfer Workshop

August 26-30, 1991
Red Lion Hotel
Denver, Colorado

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The material presented in this proceedings is of two types: invited manuscripts on assigned topics and four facilitated workshop products addressing USDA water resource cross-cutting issues for the 21st century. The issues are: wetland and riparian, water quantity and quality, instream flows and channel maintenance, and global change. The papers, including references and tables, presented here were provided as a paper copy by the authors. They were electronically read into a word processor, reformatted for uniform spacing, heading style, edited and then reprinted using a common print font. A few of the papers were provided on magnetic media and read directly into the word processor. Figures are reproduced essentially as provided by the author. The authors obtained peer review and agency approval of their paper before the workshop. The authors approved revisions suggested by the editors before publishing. Products from the facilitated workshops were placed on magnetic media at the workshop, reviewed extensively, and approved by the workshop participants. Minor editorial changes concerning format, style, and grammar were made to this portion of the proceedings.

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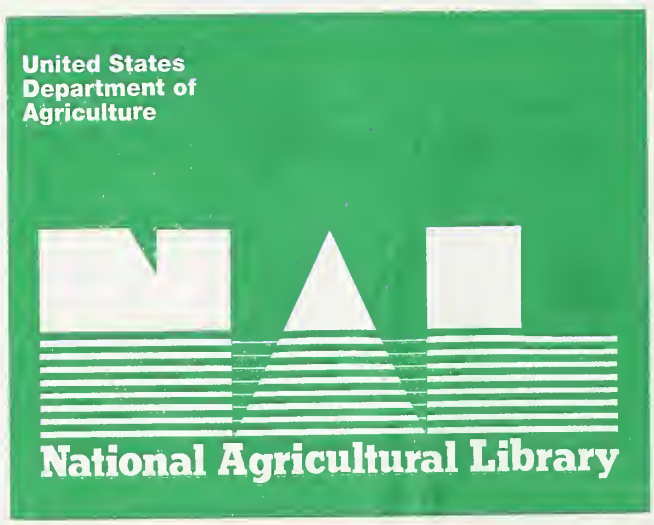

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Wilbert H. Blackburn
John G. King, Editors

Sponsored By:
Agricultural Research Service
Forest Service, Research
Forest Service, National Forest System
Soil Conservation Service

PREFACE

Water is as essential as blood and lymph for life, provides nourishment and removal of wastes for the individual cell, plant or animal, the household, the city, civilization, and the earth itself. Many things are affected by water and water affects many things as it moves in its relentlessly hydrologic cycle. Examples are plants, which regulate the rate at which a land surface returns water vapor to the atmosphere, and humans, who alter nearly all aspects of water on land. In addition to being essential for life, the amount of water, unlike other renewable natural resources, is constant and neither increases nor diminishes. Even so, on a global scale there is perceived to be more than enough freshwater to meet demands, both now and in the future. However, water is often available in the wrong place, at the wrong time, or with the wrong quality. This uneven distribution of the amount and quality of water coupled with the increasing importance society is placing on water resources is adding new dimensions to the use and management of water in the United States. Society requires that USDA maintain its technical credibility as it deals with the nations' water resource issues. Water and its intimate involvement with all aspects of the agriculture and silviculture environment will be major issues well into the next century. Societies increased interest in water resources will continue to create many challenges and opportunities for agricultural and silvicultural. It will require new knowledge, technology and enhanced inter and intra Departmental cooperative efforts to address water resource issues associated with the production of food and fiber in the 21st century.

The First USDA Water Resource Research and Technology Transfer Workshop: Water Resource Challenges and Opportunities for the 21st Century, was held at the Red Lion Hotel in Denver, Colorado, August 26-30, 1991. The purpose of the workshop was to identify and develop two or three cross cutting topics for the following water resource issues: 1) wetland and riparian, 2) water quantity and quality, 3) instream flows and channel maintenance, and 4) global change. The immediate objectives were to:

- Strengthen USDA agency cooperative efforts in water resources.
- Identify and justify the cross cutting water resource research and technology transfer issues/topics that USDA should be promoting for the 21st century.
- Compile a briefing document for use by Agency Heads, Secretary of Agriculture and U.S. Congress.

The workshop was co-sponsored by the U.S. Department of Agriculture's Agricultural Research Service, Forest Service - Research, Forest Service - National Forest System, and Soil Conservation Service. The symposium was an outgrowth of several previous meetings between personnel in the three agencies. The planning committee convened several times at the Fifth Federal Interagency Sedimentation Conference, March 18-21, 1991 in Las Vegas, Nevada, organized the workshop format, and selected the four cross cutting issues. The workshop was organized in three parts: 1) speakers from outside the department representing the government and university community, and speakers representing the upper administration within USDA and the three agencies; 2) speakers within each agency presenting status reports on each issue to set the stage for the facilitated working groups by addressing agency policy related to their assigned issue, related program(s), expertise, data base, accomplishments, funding base, future direction, and a listing of the agencies' perceived three to six most important water resource topics under the assigned issue; and, 3) facilitated working groups exploring the possibilities for developing interagency cooperation within their assigned issue. More specifically, the working groups were to determine important topic areas that are common to the three agencies, prioritize the topics and develop a rational explaining why the top three to five topics are important, develop a vision statement for each topic, identify and prioritize any major barrier and a list of recommendations to implement the vision statements and strengthen interagency cooperation. Each working group was assigned a trained facilitator and a recorder.

We give special thanks to the planning committee, facilitators and recorders listed below. We are most indebted to the authors, moderators and invited participants who made the workshop a success. Most papers and the facilitated working group's output were circulated in draft form at the workshop. We are grateful to John Blodgett, Congressional Research Service; Harry Mussman, Deputy Assistant Secretary for Science and Education; and, Andy Walch, Department of Justice for their excellent presentations. Sue Antonich, ARS, and Bobbi Fuller, Forest Service, assisted with logistics before and during the workshop, registration, and prepared the facilitated working group's output. Sue Antonich produced the proceedings and we are appreciative to her for persisting. Special thanks to Dave Farrell, ARS; Dean Knighton, FS-Research; Wendel Moody, SCS; and, Warren Harper and Larry Schmidt, FS-Nation Forest System, for their efforts in disseminating information, inviting speakers and participants, and general support for the workshop. Without the strong support of the upper administration from the three agencies this workshop would not have materialized. We are appreciative to our University Guests that so nicely represented the Universities Council on Water Resources and for their contributions to the workshop - Hanna Cortner, University of Arizona; Neil Grigg, Colorado State University; Jack Hess, Desert Research Institute, Nevada; Jim Loftis, Colorado State University; Bob Ward, Colorado State University; Tom Wesche, University of Wyoming; and, Steve Gloss, University of Wyoming.

Wilbert H. Blackburn, Co-chair

John G. King, Co-chair

Workshop Planning Committee

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OPENING SESSION

Workshop Challenge

David Farrell

Ladies and Gentlemen, on behalf of the Organizing Committee, the agency and departmental administrators, who have given their support to the workshop, and many others who have given so generously of their time and effort, I welcome you to this opening session of the First USDA Water Resources Research and Technology Transfer Workshop.

This is an opportune time for USDA agencies to begin to put together a shared vision for the future not just of the department's water resources programs, the issue that we will be tackling here this week, but for the whole program. Perhaps, the lessons we learn from this workshop will help, in a small way, to provide an insight into the challenges that will need to be met to achieve the broader program goals of USDA. Two of the questions that we hope to answer this week are: (1) Can we reach a consensus on the opportunities in water resources research and technology transfer that need to be pursued? And (2) Can we formulate feasible and effective strategies for capitalizing on these opportunities?

Questions relating to what should be included in the nation's water resources agenda during the coming decades have been receiving considerable attention. Not long ago, the National Academy of Sciences released its report on "Opportunities in the Hydrologic Sciences." Most of the water resources issues to be discussed at this workshop are included in this report from the Academy's Water Science and Technology Board. Earlier this month, I received a copy of a report from the National Research Council to the Water Resources Division of the U.S. Geological Survey entitled "Preparing for the Twenty-First Century". Among the water resources issues identified in this report are: Global Climate Change, Water Quality, Wetlands, and Drought and Flood Hydrology.

There is sufficient evidence available in the form of reports, legislative initiatives, and promotional efforts by concerned citizen groups to establish that a strong consensus already exists within the national and international scientific communities, the general public, and legislative bodies both foreign and domestic, on where the challenges and opportunities lie in water resources assessment and management. The charge to the work groups is to determine how best USDA can respond to the nation's current and projected water resources problems. What is, and what should be the USDA role? To what extent would strengthened collaboration among USDA agencies optimize resource use and capitalize on the department's diversity of disciplinary strengths, unique facilities, scientific and technical knowledge, technology delivery systems, and substantial resource data bases?

We in the USDA have several major advantages over our professional colleagues in most other water resources agencies and departments. First, we have the ability not just to develop and evaluate new technologies, but educational and delivery systems that can capitalize on these developments. Second, we have unique strengths in biology that can be harnessed to our strengths in earth sciences. Third, we have a legislative mandate to develop and promote the use of resource conservation and watershed management technologies by all major land users, farmers, ranchers, and foresters.

During the many years that I have worked for ARS and collaborated with SCS, I have had the privilege of working with some of the most talented professionals in water resources research and management. My interactions with FS, though limited, have also been positive and constructive. Are these talents being used most effectively? Do we share a common vision of what is needed? Should we? The challenge for the work groups is to address these questions, and come up with recommendations for optimizing the use of our human resources. My personal conviction, based on the discussions I have had with professionals in ARS and in the other agencies, is that strengthened collaboration will be beneficial to all USDA agencies. However, given the challenging program agenda that each agency is already facing, adjusting programs to accommodate the needs of other groups will not be an easy task. If we are to

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make real progress, what we need is a better understanding and recognitions of our strengths and limitations, the identification and development of programs that capitalize on our strengths, and a commitment to promote our common cause.

In summary then, our first task is to use this opportunity to build a shared vision for the future of USDA's water resources programs. Our second task is to work together to get our message out to those who are concerned about the nation's water problems. If we accomplish these two tasks, we will have taken a major step forward in our quest to strengthen the water resources programs of USDA, and give them the visibility and national recognition that they deserve.

Issue 1. One of the central concepts in mathematics specifies that the conditions we impose on the solution to a problem must be both necessary and sufficient. While the concept is widely used in solving the equations of mathematical physics, it has relevance to a much broader spectrum of mathematical problems. This is hardly surprising since logic itself is a branch of mathematics. An example might help to establish the relevance of this concept to the task we will be undertaking this week. Is the control of cropland erosion a solution to the problem of water quality degradation by sediments? The answer to this question is no, because landscape erosion may not be the sole source of sediments. It may not even be the primary source. The proposed solution fails because it does not satisfy the conditions of necessity and sufficiency.

Issue 2. The working group submits that soil and water conservation research cannot be effectively undertaken using any single method of approach. Some problems are best investigated only by highly organized teams at specially designed research facilities; others are attacked best by the coordinated efforts of scientists working in independent laboratories; and still others are studied most effectively by the independent efforts of investigators outside the framework of an organized national or regional structure. Whatever the method of approach, the basic unit of research productivity is still the individual investigator with a good idea. Therefore, any expansion of soil and water research should provide for adequate support of individual scientists and teams of scientists whose work may not be included in any of the highly organized projects. (Extracted from Senate Document #59)

Water Resource Issues and USDA in the 21st Century: (Abstract of Presentation)

Harry Mussman

Water resources and their intimate involvement with all aspects of the environment will be major issues from now, well into — if not all the way through — the next century. Agriculture and silviculture will be required to solve numerous water resource and environmental problems associated with the production of food, fiber, and forest products.

The scientists of the Agricultural Research Service and the Forest Service and the conservation professionals of the Soil Conservation Service are to be commended for their effort to coordinate research. You have selected four important areas: wetlands and riparian zones; water quantity and quality; instream flows and channel maintenance; and global climate. Clearly, you appreciate the complexity of the problems and the multidisciplinary approach necessary to solve them.

Farmers, ranchers, and foresters are, more than ever, going to need the scientific knowledge that you produce and the useable technology that you provide. Your efforts will underpin this Nation's ability to meet both the domestic and international needs for food and fiber while at the same time maintaining the quality of our natural environment and allowing producers to earn a comfortable living.

USDA has established the Agricultural Council on Environmental Quality (ACEQ) to coordinate the Department's programs among its own agencies and between USDA and other State and Federal agencies. Your deliberations over the next few days can provide important input to the Council in all four of the areas you have elected to discuss. I urge you to put your best thinking into this effort as you look to the 21st century and beyond.

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Six Grim Tales of Science and Public Policy

John E. Blodgett

In a recent editorial "Two Plus Two Equals Five," *Science* editor Daniel E. Koshland, Jr. interviewed Dr. Noitall, "the world's greatest authority on public relations," about the problem that public policymakers seem as responsive to public emotions and perceptions as to scientific facts.[2]

Science. But it is our job to tell people when 2 + 2 = 4.

Dr. Noitall. That's exactly where your views are wrong. A recent poll shows that 50% of the people think 2 + 2 = 5, and almost every network agrees with them. Those people have rights, they believe sincerely that 2 + 2 = 5, and you take no account of their wishes and desires. Simply imposing 2 + 2 = 4 on them is not democracy.

Subsequent letters to *Science* chastised Koshland:

... by implying that all who disagree with scientists on public policy issues are either stupid (not knowing how to "add") or malicious (rewriting the "laws of arithmetic") to their advantage, he dangerously trivializes the policy process. We cannot think of any significant public policy controversy where one side has insisted on the equivalent of "2 + 2 = 5," although we have seen quite a few where the technical evidence marshaled by one side's scientists was simply immaterial to the concerns raised by the other side.

Public policy issues with simple answers don't remain issues very long. The ones that stick around involve conflicting philosophies, values, or interests that go a little deeper than knowing how to add. Scientists who don't understand the limits of scientific contributions to policy debates risk ... political irrelevance.[3]

... "How much is 2 + 2?" Among ... [possible] answers were 2 + 2 = 5 - 1, 2 + 2 = 2 x 2, 2+ 2 = 8/2, 2 + 2 = 1 + 1 + 1 + 1, and even 2 + 2 = four, 2 + 2 = fore, and 2 + 2 = for.

It is not easy to get people to change their ideas, especially when the ideas are controversial and seemingly obvious. But if we cannot provide a new, different, or broader perspective, we may not even get their attention. Sometimes changing the question or redefining the problem is the only way to get that attention.[4]

Your task at this meeting is a demanding one. Creating a masterplan for cross-cutting research conducted by several agencies with related but different responsibilities, interests, and goals--and that is both scientifically valid and consistent with policy aims--will require taking new, different, and broader perspectives. It will require empathy; it will require a willingness to rethink one's own perspective.

Ironically, scientists are at both an advantage and a disadvantage when it comes to coordinating cross-cutting research. The advantage lies in the universality of research methodology that scientists share; the disadvantage lies in the seductiveness of relying on shared views about methodology to ignore--or even to contemn--legitimate differences in philosophies, values, and goals. Research coordination that does not go beyond methodological techniques may very well fail to meet broader needs.

Experience shows, in fact, that successful coordination and cooperation at the technical level is no guarantee that the outcome meets broader social needs and goals. I propose to illustrate the need for research coordination and cooperation to take into account other ways of adding 2 + 2 by relating six grim tales. These are true tales, and I invite you to investigate them further if they tweak your interest, since they contain lessons not only relevant to your individual and institutional success, but they have come at considerable cost and anguish to some individuals, as well as having implications for corporate income and the national treasury. I will indicate some of the morals to be drawn from these grim tales, but there may be others that speak to you as well.

Author is Assistant Chief and Senior Analyst in the Environment and Natural Resources Policy Division, Congressional Research Service, Library of Congress, Washington, D.C. 20540.[1]

The First Grim Tale - National Acid Precipitation Assessment Program

In 1980, Congress enacted legislation creating a 10-year National Acid Precipitation Assessment Program (NAPAP). Broadly speaking, the purpose of the program was to focus the nation's scientific talent on the causes and effects of acid rain, *and* on how to control it. During the next 10 years, half a billion dollars and the efforts of hundreds of scientists were expended in this unique interagency collaboration. Much was learned about acid rain, its causes and effects. But the impact of this endeavor on public policy was virtually nil, for two fundamental reasons. One was timing: Congress was putting the *finishing* touches to the Clean Air Act Amendments of 1990--legislation that includes a substantive acid rain control program that will cost some $3 to $4 billion per year in the next few years--while NAPAP was still issuing penultimate drafts of 27 State-of-Science/Technology reports and a draft "integrated assessment." The second, equally important reason, was that NAPAP's science did not encompass several key policy issues.

Several instructive post mortems of NAPAP have appeared in the literature. Excerpts from two will give their flavor, but I urge you to read the originals. The first is from *Science* magazine's 'News and Comment' section and reviews the political history affecting the assessment; the second analyzes the assessment itself in terms of technical and policy completeness and relevance.

While NAPAP created an impressive body of scientific research over the decade, in terms of policy, says one congressional aide, it was "totally irrelevant."

> Most of NAPAP's eventual shortcomings ... can be traced to how it defined its universe--which was by and large in terms of scientific curiosity and not policy relevance. From the outset, says [Dr. Milton] Russell and others, NAPAP saw itself as a scientific research program, not an assessment program .... Explains Russell: "Instead of asking, What do we really need to know to make the wisdom-
> type calls Congress will be called on to answer over the next 10 years, NAPAP managers asked, What are the intriguing and seminal scientific questions we can answer in 10 years." What's more, they seemed to operate on the naive assumption that
> Congress would wait for their answers.

[NAPAP's second Director, Lawrence] Kulp brought in a disdain for anything less than "hard science." His view, from the outset, was that NAPAP should stick to the facts and leave the interpretation to someone else. Likewise, he considered economic analysis of the costs and benefits of controlling acid rain to be squishy and premature and abolished that part of the program. Russell concedes that economic analysis is messy and complicated, compared to analyzing lake sediments, for instance. But, he adds, "it would have been very useful for Congress to know, in a rough and ready form, the benefit of one level of emissions reductions versus the costs."[5]

While the NAPAP program has yielded many important scientific accomplishments over the past ten years, the final integrated assessment, intended primarily to help inform public policy, unfortunately, falls far short of what might have been hoped for at the outset of the program, specifically with regard to the benefits and costs of acid rain controls....

The principal lesson for future large-scale assessments is to start early, stick with it and iterate often. The assessment should be driven by policy-oriented questions that serve to shape the research agenda....

... Assessments are part of a learning process that pulls people together to develop information and insights that might not otherwise be developed. In the last analysis, a lot of interesting scientific research simply does not matter in driving and shaping public policy. Thus, we need to work hard at sorting out the things that matter most from those that are less important, and at identifying critical gaps in on-going R&D activities. This is part of what integrated assessments can help to do. The process must be iterative. Over time, assessments should shape the "conventional wisdom" that eventually emerges. Doing this right requires not only good science, but sustained efforts to communicate technical results to policymakers and policy needs to scientists, because there is resistance and communication gaps in both directs. Finally, we should understand that the best scientific models alone are not necessarily the best tools for integrated assessments. There is a need for a hierarchy of models, data and judgments with different levels of complexity and complementary strengths and capabilities that can help provide a range of insights for addressing complex

environmental problems.[6]

The NAPAP tale has received much attention because the program has been seen as a model for studying other complex and multidisciplinary environmental issues, such as climate change. In extracting a moral from this tale, I would highlight three themes: (1) Hard scientists may be able to restrict their research to hard science, but the policymaker does not have that luxury. Economics may be a soft and squishy science, but a policymaker cannot for that reason ignore the economic consequences of policy, nor the social and ethical implications. (2) For interagency and interdisciplinary projects, the language of science may provide a useful common basis for discourse--but that language is frequently inappropriate for communicating with policymakers. Thus one of the tools that can help you, as scientists, coordinate and cooperate despite differences in discipline and agency--a common language--may at the same time exacerbate your difficulties in communicating with the policy community. And (3), the scientific and policy communities operate in different cultures. For example, a scientist, faced with uncertainty of a result, can defer a conclusion and repeat an experiment; a policymaker's timing is often much more constrained, since no decision or a delayed decision may itself be untenable. Or, a scientist's interpretation of a phenomenon is ratified by experiment and peers, while a policymaker's interpretation is ratified by the outcome, including perceptions of the outcome by nonpeers.

The Second Grim Tale - Zero Discharge Shall be the Goal

In 1972, Congress radically redirected the nation's water pollution control program. The earlier concept of regulating pollution on the basis of the quality of receiving waters was rejected; replacing it was a program based on technological effluent limitations, with "the national goal that the discharge of pollutants in the navigable waters be eliminated ...." Many interests resisted the change; and scientists, engineers, and economists were virtually unanimous in rejecting the new direction. An article reviewing the evolution of the revised Act assessed the technical community's contribution in the hearing record and concluded:

> ... [T]he image of the technical community that this record projects is one of cautious, defensive conservatism....
>
> The majority of technical opinion was in favor of the status quo as it existed prior to enactment of PL 92-500 [the Federal Water Pollution Control Act Amendments of 1972]. The majority of suggestions from the technical community were of a sub-optimizing nature. The majority of concern was with the costs of pollution control.[7]

Russell Train, Chairman of the Council on Environmental Quality, and Paul McCracken, Chairman of the Council of Economic Advisers, summarized the costs argument:

> Mr. TRAIN. ... [T]he marginal costs of abatements increase greatly as higher levels of reductions are required. For example, EPA estimates that as a general proposition 85-percent reduction costs only 20-percent as much as 100% reduction.
>
> To go from 95-percent treatment to 98-percent treatment costs the same as going from 85- to 95-percent treatment... The last percent of reduction often costs as much as the first 99-percent.
>
> Mr. MCCRACKEN. This rapidly rising incremental cost was something to which Chairman Train alluded in his testimony. The incremental costs at this point is so large as to start to raise serious questions about the economic feasibility of carrying the removal level to 100 percent.
>
> The question is not answered by whether even purer water is better but whether after achieving a reasonably high level of removal the large resources involved to achieve small further gains would contribute even more to our material welfare....
>
> This question is complicated by our current lack of complete knowledge about the relationship between the levels of pollution removal from certain specific sources and the overall quality of water that results.
>
> This is especially true in areas where runoff from farms or mines is an important contributor to the final quality of the water. CEA is in agreement with the use of water quality targets appropriate to the conditions and expected uses of water in particular areas of the country.
>
> That is basic to the concept of relating the costs of programs to the benefits received from them. To abandon that concept for a nationally legislated standard which focuses on the level of pollutants removed and is unrelated to water quality uses and standards is economically

unwise because it means a necessary misallocation of our inevitably scarce economic resources.

This is especially true when the stated goal is for the removal of all effluents.[8]

One exception to the technical community's negative response to the zero discharge goal was Daniel Evans, an engineer who knows politics--at the time he was governor of Washington:

Governor EVANS. ... [S]trong effort is needed in terms of research. There was a good deal of testimony and some controversy ... today on the economics of water pollution control. I speak, of course, not as an economist, but I do speak as an engineer and ... the concern and question of rapidly increasing costs, for those last few percentage points of pollution removal may be radically changed, and I think will be radically changed if we have a clear statement of a national commitment, and ... if we do that, I would be disappointed if ... the scientists and the engineers of this country ... did not come up with the new and changed technology that may very well not cost more, but may well cost less to achieve.

[For example,] ... some of our pulp and paper industry ... are ... in the process of trying to put together a closed cycle process which would end all pollutants, air and water, and to do it in an economical fashion....

Now, if that happens, then of course the traditional way of handling pollutants by treatments suddenly is changed, and the cost, especially the incremental costs at the very end of the process, the 98, or 99, or 100 percent, are radically changed and those costs simply are not in the magnitude we are looking at today.

I am saying I have confidence in the technology of this Nation. I think what we really need is a national commitment and the national commitment is stated very well I think in the bill before you.[9]

Nevertheless, the technical community continued to view the "zero discharge" goal narrowly from a technological perspective, failing to account for its policy ramifications. For example, here is what a 1974 report of the Council for Agricultural Science and Technology said about it:

A national policy of zero discharge of pollutants into waters is contrary to previous water quality control policy, denies use of waters for human waste disposal even though waste disposal is an inherent natural function of waters, contradicts the statutory requirement for practicable "state of the art" control technology, and negates water quality standards based on compromise among various human needs.[10]

Given the technical community's "business-as-usual" approach to water quality when "zero discharge" was enacted, the experience of 20 years is instructive. Here are remarks of Robert Luft, Senior Vice President of Du Pont Chemicals, made in 1991 on "safety and environmental stewardship" in the chemical industry:

We've faced barriers in this important work, too many of them self-generated. Have you heard yourself or your colleagues saying:
—"It's too expensive."
—"It really won't help the environment."
—"The technology isn't available."
—"Our manufacturing process depends on existing equipment."
Sound familiar?

I'm happy to say, we have many examples where those barriers have been overcome.

Our continued existence requires that we *excel* in safety and environmental performance. Our future is dependent on the non-objection--indeed even the support--of the people and governments in the countries and communities where we operate. The polls tell us that the public is rapidly losing patience with industry. This is particularly true when we present scientific arguments and technical solutions to problems best addressed by common sense and sensitivity to public concerns.

After reviewing numerous examples in which Du Pont has successfully addressed pollution problems, Luft concluded:

Our goal must be zero-waste--to make something useful out of every molecule of raw material, We can accomplish this through better understanding and control of our processes--in some cases, by reducing the complexity of our processes. We must assign our best people to environmental programs. They will get us to "zero waste" sooner.

We must shift our mindset from "meeting regulations" to "meeting public expectations." We must be proactive, not reactive.[11]

This corporate recognition of the zero discharge goal reflects numerous forces: one is that if you hit someone over the head long enough and hard enough, they begin notice; a second has been the "closing circle" of environmental controls that has progressively shut off alternative disposal routes; a third has been "public right to know" requirements that make public the discharges of individual firms.

In any event, the most important fact about "zero discharge" is that it refocuses one's view: as Luft said, "*We must shift our mindset.*" That is what "zero discharge" is about: whether one thinks first about engineering a filter to control the last percent of discharge, or, instead, thinks initially about the kind of process involved and if the discharge is necessary at all.[12]

The Third Grim Tale - Exploring Alternative Agriculture

When the National Research Council's report *Alternative Agriculture* appeared in 1989, it generated controversy reminiscent of the 1964 appearance of *Silent Spring.* Noting that agriculture is the largest nonpoint source of water pollution, that agrichemicals are being found in groundwater, that pest resistance continues to grow, and that the safety of pesticide residues in food remains controversial, the NRC report propounded the need for a shift from "conventional agriculture" to "alternative agriculture." This proposed shift would be one of management attitude. "The hallmark of an alternative farming approach is not the conventional practices it rejects but the innovative practices it includes."[13] The most controversial part of the report concerned its focus on the potential for lowering agricultural inputs, especially pesticides and fertilizers, through better management and exploitation of natural biological relationships such as between pest and predator and of natural processes such as nitrogen fixation, instead of relying on chemically-intensive methods.

During the ensuing controversy, Congressman Lee Hamilton, Chairman of the Joint Economic Committee, asked the Council for Agricultural Science and Technology to prepare an assessment of *Alternative Agriculture.* The resulting CAST report consisted of reviews by over 40 scientists and specialists. The tenor of these individual reviews ranged from highly supportive to sharply critical. While the CAST report did not take a position on the validity of the NRC report per se, it indicated that the NRC report's blurred distinction between alternative and conventional agricultural took the debate outside the realm of scientific inquiry:

> ...[O]ne of the problems identified early in the project was the difficulty in differentiating between alternative and conventional agriculture. The lack of clarity in the definitions of the two systems is illustrated by a statement made on page 425 of the NRC report. The statement reads, "Conventional and alternative systems may use common practices or methods, but they usually differ in overall philosophy." The purpose of CAST is to evaluate scientific information, not philosophical issues. Therefore, this document will not discuss the philosophical differences between alterative and conventional agriculture. It will address the issues related to the scientific aspects of Alternative Agriculture.[14]

At a congressional hearing on *Alternative Agriculture,* John Pesek, Chair of the Committee that prepared the report and John Goodman, a member of the Board on Agriculture, commented on the question of philosophy in their testimony:

> Mr. GOODMAN. I think it is not inappropriate ... that we examine different philosophies about what the future of agriculture would look like, although I think that to speak only to the difference being one of philosophy is to minimize an important difference that might be drawn between what the NRC report and what many of the CAST reviewers have said about it.
>
> The point simply is that we are talking about alternative approaches or alternative ... emphases placed on the approaches used to manage the farming enterprise ....[15]

In their written statement, Pesek and Goodman expanded on the practical implications of the different philosophies:

> *Alternative Agriculture* makes it very clear that there is more to the difference between alternative agriculture and conventional agriculture than philosophical orientation.... Alternative agriculture systems, in contrast to most conventional systems, rest upon the sophisticated management of biological and ecological cycles, forces, and interactions that lie at the heart of all farming operations.
>
> The degree of concern and attention to the long-term sustainability and performance of

farming systems is central to the distinction between alternative and conventional agriculture. Farmers who have pioneered alternative agriculture systems tend to evaluate farm productivity over at least a few multiyear rotational cycles. They are inclined to ask questions about the impact of current production practices on the longer-term sustainability and profitability of production practices measured in terms of human health and impacts on wildlife, from the perspective of food safety, and relating to natural resources and environmental quality. Such a long-term view will be needed for agriculture to respond to society's growing concern about the environment, yet a farmer's time horizon is, as a practical matter, becoming progressively shorter, collapsed by the need to assure economic survival, comply with government program rules, and need community norms and expectations.

Farmers utilizing conventional systems share these same concerns, but tend to evaluate the performance of a farming system more narrowly in terms of per acre yields and profits in a given year. Also, they tend not to consider such a wide range of off-farm consequences or alternative cropping patterns, agronomic practices, and technologies in the design of farming systems. A practitioner of alterative agriculture would readily consider a change in crop rotation practices on a given field to bring a particular pest under control, or to lessen reliance on a purchased input that is becoming more expensive, A conventional producer would tend to stick with the same cropping pattern, and seek some other solution or a new production input to solve problems that arise.[16]

In short, "alternative agriculture" generates controversy precisely because it is a new emphasis, a new *mindset*, just as zero discharge for industrial polluters was 20 years ago. One can only wonder if, in the year 2010, CAST's narrow technical perspective will prove to have once again missed the implications that a redefined policy goal can have on refocusing the mindset of managers.

Perhaps the most important moral to be drawn from these three grim tales is the critical importance of mindset--or mindsets--that structures how one sees an issue or problem. One's mindset contains elements derived from personal preference, professional training, and institutional affiliation. The resulting framework, or *ethic*, to use Aldo Leopold's term, genuinely matters: "An ethic, ecologically, is a limitation on freedom of action in the struggle for existence. [It provides a] mode of guidance for meeting ecological situations so new or intricate, or involving such deferred reactions, that the path of social expedience is not discernible to the average individual."[17] For the decisionmaker, it guides a choice when data are ambiguous, when values conflict, when future implications are uncertain. Scientific methods usefully add knowledge to decisions, but it is one's ethic that puts that knowledge into context. Browsing the literature--and meetings like this one--reveals that a significant portion of the agricultural community is actively seeking a new, responsive ethic.[18]

A second moral of these tales is that not only must one have an ethic, but one must *also* recognize, be sympathetic to, and be responsive to the mindsets of others. For many years the agriculture community had a relatively coherent and stable ethic; today, that mindset is increasingly being impacted by mindsets of others--such as the environmental community.[19] The two communities approach certain problems very differently: for example, the agricultural community has long presumed that any pollution problems arising from agriculture should be seen as a social cost of abundant, inexpensive food and fiber; and that if society wishes to control agricultural pollution, then society should provide financial incentives for voluntary actions to abate the problem. Conversely, the environmental community generally believes that polluters should pay to reduce pollution, with a regulatory program to ensure environmental quality protection.[20]

While elements of the agricultural community are rethinking their ethic--especially those having to interact with other communities--the core of the community seems to be actively resisting change. Unless the agenda of agriculture responds to and complements these alternative perceptions and agendas--which will sometimes be contradictory, sometimes competing, sometimes complementary--the less socially responsive agenda risks submergence.

The Fourth Grim Tale - Rural Clean Water

That the mindset of the agricultural community's core has difficulty responding to new issues is illustrated in the fourth grim tale. When professional jokesters meet, they tell their stories in shorthand. Since they know all the jokes, they save time by numbering them, and banter by calling out the numbers. Fourteen! Thirty-nine! The story goes that an outsider at a convention of

professional jokesters was puzzled by the silence following each number--except for one grizzled veteran who broke up laughing when eighty-two was called out. "Why is he laughing?" asked the novice. "Because he hadn't heard it before," explained another veteran. Since most of you know this grim tale, I tell it only by its acronym: RCWP.

If you need the full story, ask around.[21] It has a sad ending: competition between two agencies *within* the Department of Agriculture stymied research to assess solutions to nonpoint source pollution. The ultimate consequence appears to be that responsibility for controlling agricultural nonpoint source pollution may have been effectively subrogated to the Environmental Protection Agency. Thus not only must one be responsive to the social context beyond one's profession, but also one must take into account the internal tensions of one's own professional community.

Introduction to the Fifth and Sixth Grim Tales

While the morals that I have drawn from these tales are general, I have some specific comments on the various draft papers for this conference on Water Resources Challenges and Opportunities for the 21st Century:

1. Several of the papers talk about *multiple use* as a goal for shaping policy into the 21st Century. I suggest that multiple use itself is a mindset that may need rethinking. For policymakers, the concept 'multiple use' is proving an ineffective guide when competing uses are in fact incommensurate--when you can have one use but not both--for example, water for instream flow or water diverted for irrigation, wilderness or development. I increasingly hear alternative concepts being advanced, including:
   - cost-benefit
   - best use
   - sustainable use
   - ecosystem viability
   - mixed use.

   As an ethic or mindset, each of these has distinctive implications for scientific research and for policy choices. It is worth thinking about which one, or what mix of them, might usefully undergird your coordinated efforts.

2. As a related point, I sense a need for more attention to the economic and ecosystem dimensions of the discussions. There is a need for discussions not only of economic costs and benefits, but most especially for noneconomic impacts, both negative and positive, with particular attention to ecosystem values.[22]

3. From my perspective, the workshop papers did not devote adequate attention to the following issues:
   - Estuaries. The water quality of estuaries is attracting increasing attention. The importance of this is underscored by research on Chesapeake Bay that shows agriculture to be the predominate source of pollution degrading the Bay.[23]
   - Institutional change as an alternative to technological change. This parallels the point that the "philosophy of alternative agriculture" is a different way of thinking about where the solution to a problem may lie.[24] At various points in reading the draft papers, I wondered whether nontechnological changes concerning, for example, *water pricing, grazing fees*, or *land use* requirements didn't deserve identification as provocative alternatives. In some cases, organizational changes may be necessary.[25]
   - Consistency versus site-specific. To me, perhaps the most critical issue in addressing water policy is the tension between consistent policies that treat competing interests equitably and the need to allow local variations that take into account the practical variations in soil, climate, water availability, and so on. Because of this tension, any proposal you make for water resource policy coordination is likely to be challenged; unless you have openly acknowledged and addressed this dilemma, you will be unprepared for those challenges.
   - Air. The long-range transport of pollutants via air, including agrichemicals, is increasingly viewed as an important problem. Some studies indicate that air transport is perhaps the single largest contributor to toxic pollution of the Great Lakes. The Clean Air Act Amendments of 1990 require EPA to study air pollution affecting the Great Lakes, Lake Champlain, and estuaries, with a report due in 1993 and biennially thereafter.

4. There needs to be more attention to research on the adoption and maintenance of Best Management Practices. This is critical to the "development of decision support systems to provide farmers, irrigators, ranchers and managers with decision assistance in selecting optimal management practices in the production of food with minimal environmental effects from agricultural chemicals"[26]--a point equally valid

with respect to foresters, miners, and others whose stewardship affects the land. The adoption and maintenance of BMPs appears to be the weakest link in promoting sustainable land stewardship, and a perception that traditional agricultural scientists and extension personnel lack commitment to fostering alternative agriculture probably explains why proponents have been turning away from traditional research and extension venues to demonstration projects, as noted by one of the CAST reviewers of *Alternative Agriculture:*

> Some administering low input sustainable agriculture programs appear to be skeptical of university scientists. As expressed in the NRC report, there appears to be a trend away from use of the traditional research and technology transfer system toward more on-farm trials with demonstrations not necessarily involving extension.[27]

Iowa exemplifies a State that is making intensive use of demonstration projects in its effort to mitigate excessive use of agrichemicals that can contaminate groundwater. This effort, which does make use of the existing extension system, is looking quite promising. The programs have shown the ability to reduce input costs, save energy, and reduce the loading of nitrogen and pesticides.[28]

5. Finally, the numerous and diverse papers in the Workshop workbook should contain numerous opportunities for research synergy: programs that can serve multiple purposes, perhaps better than separate efforts. For example, whatever one's view of the possibility of climate change, some relevant research and policy initiatives are probably worth pursuing in any case. For example, enhancing energy efficiency may serve several goals, including reduced agricultural input costs and less environmental degradation.

To conclude, I have two complementary tales about informing debate: sometimes those who have the information don't want to tell, sometimes those who need the information don't want to hear it. The first is about the "Superfund" law, the second about agricultural water pollution.

The Fifth Grim Tale - Superfund: Who Needs It?

The year before Superfund was enacted, I was asked by a Congressional Committee to analyze how a proposed tax on feedstock chemicals to fund the program would affect costs in the chemical industry and the prices of products. Since most relevant data would reside within firms within the industry, I proposed a workshop at which the requesters could discuss their question with industry representatives. I tapped several contacts at the Chemical Manufacturers Association and individual firms; I explained the issue and asked for their participation. It was agreed that the discussion would be 'off the record' so participants could feel free to speculate as necessary.

Turnout for the workshop was excellent. The requesters explained that a feedstock tax was one proposed mechanism for funding Superfund, which would be dedicated to cleaning up "orphaned" hazardous waste sites, and they were concerned about its possible impact on inflation and competitiveness. The first industry speaker described how the industry is organized. The second, who was to discuss how changes in feedstock prices because of the tax might flow through to affect costs and product prices, began by saying: "We in the industry do not believe that Superfund is necessary and that such legislation should not be enacted. We therefore will not discuss possible impacts of costs because that might imply that we think its enactment is acceptable."

Not surprisingly, the requesters were not pleased. And of course the reality was that Superfund became law the next year, and it included a chemical feedstock tax. While this one instance of the speaker's stone-walling may not have significantly impacted the legislative process, the general attitude created an atmosphere of confrontation, and certainly the drafting of the legislation and its enactment was less informed than would otherwise have been the case.

The Sixth Grim Tale - Agricultural Pollution and the Invisible Messenger Or, You Don't Have to Shoot the Messenger if you Bar the Door

At House Committee on Public Works hearings on the Federal Water Pollution Control Amendments of 1972--the same amendments that established zero discharge as the water quality ethic--Dr. Patrick Bosley, a County Health Office from Minnesota, presented a slide show and testimony about agricultural water pollution. At the end of the graphic and compelling presentation Committee Chairman John Blatnik noted that there was a jurisdictional problem:

> The CHAIRMAN. We cannot write agriculture legislation [which is under the jurisdiction of the Agriculture Committee]. We do have jurisdiction over the watershed program, and I

do not see why we cannot work that in with the Soil Conservation Service....

Dr. BOSLEY. ... I would say about this presentation that I could really not have given it to an Agriculture Subcommittee because I think I would probably have had to wear a bulletproof shirt.

Committee Member Clarence Miller followed up:

Mr. MILLER. The material you have presented is very good, and I am wondering whether you have had the opportunity to appear before the Agriculture Committee ...?

Dr. BOSLEY. The point, if I may speak to that point briefly, is that insofar as testifying before a Federal agricultural committee, I have tried repeatedly unsuccessfully.[29]

One moral of this tale might be that ignoring a problem doesn't mean it will go away. Or, if you shoot the messenger, the ricochet may hit you in the foot. There may also be a moral in the fact that Dr. Bosley, a health professional, was not of the agricultural professions: there is a complementary tale of the Emperor's clothes.

The CAST reports on zero discharge and alternative agriculture, the RCWP, and Dr. Bosley's experience provide a measure of the rigidity of the agricultural community's traditional mindset. Today, clearly, change is in the air: the crucial question is whether that change will be imposed from without (a possibility warned of by Sandra Batie[30] and others), or unfold from within (as advocated by the previously cited writers in the *Journal of Soil and Water Conservation*,[31] the NRC report, and others).

Sometimes someone's numbers don't add up. Then the question is, What do you tell, and to whom do you tell it? A robust ethic and a sensitivity to the policy setting are critical to finding the answers. Sometimes two plus two does equal four.

Notes and References

1. The views and opinions expressed in this paper are solely the author's and do not necessarily represent the position or policies of the Congressional Research Service.
2. *Science* (23 March 1990), p. 1381.
3. Gerald L. Epstein and William C. Clark, *Science* (8 June 1990), p. 1174.
4. Michael R. Cohen, *ibid.*
5. Leslie Roberts "Learning from an Acid Rain Program," *Science* (15 March 1991) pp. 1302-1305. See also, from Letters to the Editor, *Science* (14 June 1991), pp. 1474-1475.
6. Edward S. Rubin, "Benefit-Cost Implications of Acid Rain Controls: An Evaluation of the NAPAP Integrated Assessment" *Journal of the Air and Waste Management Association* (July 1991) pp. 914-921.
7. David E. Gushee, "Clean Water: What Is It? How Will We Achieve It?" *Chemtech* (June 1973), pp. 334-344.
8. U.S. Congress. House. Committee on Public Works. *Water Pollution Control Legislation—1971* (H.R. 11896, H.R. 11895). Hearing 92d Congress, 1st session. (Washington, D.C. Govt. Print. Off., 1972), pp. 202, 213-214.
9. Ibid., p. 271.
10. Council for Agricultural Science and Technology, *Zero Concepts in Air, Water, and Food Quality Legislation*, Rpt. No. 31 (12 August 1974), p. 1.
11. Robert v.d. Luft, "Protecting the Environment: It's Good Business," Remarks, at the National Petroleum Refiners Association International Conference, San Antonio, Texas (26 March 1991), pp. 1, 9.
12. 'Zero' as a *policy goal* should not be confused with 'zero' as a *regulatory standard*. In the latter case, 'zero' means nondetectable, which is contingent on changes and improvements in assessment techniques and measuring capabilities. Paradoxically, a zero regulatory standard can actually contravene a risk minimization policy: see Board on Agriculture, National Research Council, *Regulating Pesticides in Food: The Delaney Paradox* (Washington, D.C.: National Academy Press, 1987); and Institute for Science in Society, *Unraveling Delaney's Paradox: Challenges for the 102nd Congress* (Washington, D.C., ISIS, 1991).
13. Committee on the Role of Alternative Farming Methods in Modern Production Agriculture, Board on Agriculture, National Research Council, *Alternative Agriculture* (Washington, D.C., National Academy Press, 1989), p. 3.
14. Council for Agricultural Science and Technology, "*Alternative Agriculture*" *Scientists' Review*, Special Publication No. 16 (July 1990), p. vii.
15. U.S. Congress. House. Joint Economic Committee. *Alternative Agriculture: Perspectives of the National Academy of*

Sciences and the Council for Agricultural Sciences and Technology. Hearing 100th Congress, 2d session. (Washington, D.C.: U.S. Govt. Print. Off., 1990), 309-310.

16. Ibid, pp. 292-293.
17. Quoted by Andrew Walsh in a presentation at the Water Resource Challenges and Opportunities for the 21st Century Conference: Andrew F. Walsh, "Development of a Water Resource Agenda for the 21st Century—Thoughts from a Legislator's Perspective" (p. 18).
18. For example, the first four articles of the first 1991 issue of the *Journal of Soil and Water Conservation* (January-February 1991) are: "Viewpoint: 'New Perspectives' for the Forest Service": Winifred B. Kessler tells how the Forest Service is attempting to dispense with "business as usual" as a means of staying in tune with public values; "Sustainable Development: Growth without Losing Ground": Derek Doyle looks at the issues confronting natural resource managers in achieving economic growth without undue environmental degradation; "Do We Have a National Water Policy?": Theodore M. Schad says water policy in the United States generally has come too little and too late; and "Water Futures": Jan van Schilfgaard outlines the principles around which to formulate a new national water policy.
19. Sandra S. Batie, "Agriculture as the Problem: New Agendas and New Opportunities," *Southern Journal of Agricultural Economics* (July 1988), pp. 1-11.
20. Jeffrey A. Zinn and John E. Blodgett, "Agriculture versus the Environment: Communicating Perspectives," *Journal of Soil and Water Conservation* (May-June 1989), pp. 184-187.
21. See R. Neil Sampson, *For Love of the Land* (League City, Texas: National Association of Conservation Districts, 1985), pp. 221-225.
22. Donn DeCoursey. 1991. "Status of Water Quantity and Quality Program: Agricultural Research Service, p. 70. In: Water Resource Challenges and Opportunities for the 21st Century. Proc. of the First USDA Water Resource Research and Technology Transfer Workshop.
23. Ibid.
24. See William B. Lord, "Institutions and Technology: Keys to Better Water Management," *Renewable Resources Journal*, vol. 3, no. 3 (Summer 1985), pp. 17-21.
25. For example, Janne Hukkinen, "Irrigation-induced Water Quality Problems: Can Present Agencies Cope?" *Journal of Soil and Water Conservation* (July/August 1991), pp. 276-278, contends that "Before the techno-economic dimensions of the return flow issue can be dealt with, a fundamental restructuring of agency responsibilities and regulatory processes is required."
26. Donn DeCoursey. 1991. "Status of Water Quantity and Quality Program: Agricultural Research Service, p. 70. In: Water Resource Challenges and Opportunities for the 21st Century. Proc. of the First USDA Water Resource Research and Technology Transfer Workshop.
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28. *Integrated Farm Management Demonstration Program 1990 Progress Report* (Ames, Iowa: Iowa State University Extension, January 1991); "Chemical Dealers Use Nitrogen Test, Slash Fertilizer Rates on Client Farms," *Integrated Farm Management Notes*, no. 6 (Winter 1990) (Ames, Iowa: Iowa State University Extension), p. 1.
29. U.S. Congress. House. Committee on Public Works. *Water Pollution Control Legislation--1971 (Proposed Amendments to Existing Legislation)*. Hearing, 92d Congress, 1st session (Washington: U.S. Govt. Print. Off., 1971), pp. 2193-2194.
30. See footnote 19.
31. See footnote 18.

Development of a Water Resource Agenda for the 21st Century - Thoughts from a Litigator's Perspective

Andrew F. Walch

Introduction

Good evening. It is an honor to be here at the beginning of this magnificent and timely effort to redefine for the 21st Century the goals and aspirations of the Forest Service, Forest Service Research, the Soil Conservation Service and Agricultural Research Service. Out of all of the agencies of the federal government dealing with natural resources, you are probably closest to the land itself. Thus, you have a special obligation to take care in shaping your agenda for the 21st Century.

You are scientists; I am a lawyer. What can I as a government lawyer tell you that may be of assistance in the important, far reaching and exciting effort you are just beginning with this meeting?[1]

Some people view lawyers as impediments to progress. In fact, John Naisbett, author of MEGATRENDS, wrote that, "Lawyers are like beavers: they get in the mainstream and dam it up." Rather than being a beaver this evening, I hope that I can pass on to you a little of what I have learned in my years of representing the government in court, especially in this latest case for the Forest Service, so that you walk away from this evening thinking that your lawyers can actually further and promote your cause rather than simply be an impediment to the flow of the mainstream, or to knowledge. For eventually, given today's complex society, what you do in the years ahead based on the agenda you create here this week -- odds are some of you will end up in a court of law defending your science and the decisions based on it. Some of you already have.

What I will suggest to you in this talk is that there lies in your rich past, the traditions of this Department, guiding beliefs that can be used to set the tone for your agenda for the 21st Century. This thought comes from Dr. Luna Leopold, the pre-eminent scientist in the field of fluvial geomorphology and the son of the late Aldo Leopold.

In a distinguished lecture to the National Academy of Sciences last year, Dr. Leopold talked about the need for an overriding ethos, or guiding beliefs, that should apply to water resource management.[2] Dr. Leopold stated, "Policy can be written in explicit terms and can be in the form of an order. Ethos is less explicit and includes a view point -- a guiding value understood but not necessarily written out." Water development, according to Dr. Leopold, should be governed by this concept: "decisions in the field of water development and management should aim toward the preservation of the integrity of the hydrologic continuum" i.e., the "sustainability" or maintenance of a balance of processes within the hydrologic cycle.[3]

I will be coming back to this later. Suffice it to say at this time that of the scientists who testify in court, those who have developed an ethos or principles that they strive to achieve and on which their work is focused, who believe in their work, they come across as much more credible than those who don't.

This is an exciting time to be a Department of Justice attorney. Every day we litigate cases that require us to present, promote, protect and defend the cutting edge of technology that specialists like you are developing to preserve and protect the nation's resources, especially those related to water.

Department of Justice attorneys already are defending cases that will require immense cooperation and transfer of technology among the different agencies of government and among the scientists within those agencies. Our cases already deal with global warming, wetland preservation, water quality and the preservation of ecosystems - all of which came together in liltigation on the Florida Everglades; and, of course, throughout the West we are asserting water rights claims to both surface and groundwater for national forests, national parks, wild and scenic rivers, and other public lands reserved for specific purposes.

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Forest Service Instream Flow Quantification Litigations - Colorado

Research and technology transfer was an integral part of the case I have spent the past 3 years on here in Colorado involving the reserved water rights claims for national forests. Congress, in establishing the national forest system in the West, determined that they were to serve the purposes of providing a supply of timber and to "secure favorable conditions of water flows" - the language Congress used in the Organic Administration Act of 1897.[4] Preparation of the case for trial involved the transfer and coordination among the witnesses of all aspects of the history of the Organic Act, and of the science, research and analysis, and data collection underlying the technical case. The witnesses included private consultants, academicians, and scientists from the U.S.G.S., Forest Service Research and the Forest Service.

Determining what was meant and what amount of water was to be claimed required an examination of the physical and biological response of the watershed to the loss of streamflow, as might happen if all the water is diverted or stored under what would otherwise be a junior water right. To understand the watershed response and predict what would happen if and when normal and flood flows return to the old, pre-diversion channel, experts were called in the fields of hydrology, sediment transport, geology, fluvial geomorphology, dendrochronology, hydraulics, riparian ecology, and watershed management. Two historians testified about events leading up to and surrounding the enactment of the Organic Act of 1897, which set forth the purposes for which national forests were established.

George Leonard[5], Gary Cargill[6] and Gray Reynolds[7] all testified on policy questions having to do with management of the forests and re-stated the national policy of claiming instream channel maintenance flows to secure favorable conditions of water flows in national forests. And, where appropriate, special use permits involving water development may be conditioned on by-pass flows necessary for maintenance of stream channels in the national forests.

Nuts and Bolts - Ideas for an Agenda

In shaping your agenda, this is your chance to seize the high ground, to give voice to the deep-felt concern of the American people for the protection of the natural resources of this land, and to demonstrate leadership among all the federal agencies in defining your agenda for the 21st Century.

You are not alone in considering this matter. Dr. Farrell mentioned the National Research Council report to the U.S.G.S. on preparing for the 21st Century. The National Park Service will be meeting in October, in Vail, Colorado, (located in "Colorado's spectacular White River National Forest") to consider the topic, "Our National Parks - Challenges and Strategies for the 21st Century." The first critical issue identified by the Park Service is the "growing negative effects on park resources from inside and outside park boundaries, ranging from visual intrusions to species destruction, and vandalism to habitat loss." Certainly, on the negative effects on park resources from outside park boundaries, the strategies you develop here are going to overlap with those of the Park Service.

So, although you have your work cut out for you in destroying the barriers to communciation and technology transfer just within the Department of Agriculture, do not be provincial in your outlook -- you have a lot to offer the Park Service, the Fish and Wildlife Service, the Corps of Engineers, the Bureau of Reclamation, the U.S.G.S., and the EPA on land stewardship, and they, in turn, can help you out. Do not limit your view in fashioning your agenda; provide for the outreach and exchange of ideas and technology, not only of the end-product of your studies but the shaping of those studies to cross inter-disciplinary lines. The dendrochronologist may have a solution to the question of streamflow quantities, the vegetation expert on sediment supply, and the historian on recent watershed history.

There are some nuts and bolts things that any agenda for the future must consider. Consistent policies and procedures among agencies are needed for the preservation and protection of instream flows for channel maintenance, water quality and quantity, fisheries, wetland and riparian zones, etc. Without such consistency from agency to agency and, even more importantly, within each agency -- the Forest Service, the Soil Conservation Service -- the legal and scientific defensibility is undermined, to the potential detriment of the stream systems.

In almost all of my lawsuits involving natural resources, and especially those that relate to change in the natural system over time, such as the latest case seeking instream flows for channel maintenance, I often have to draw upon the knowledge of geologists, geomorphologists, climatologists, dendrochronologists and historians

to put into an historical perspective the physical conditions we see today. It is absolutely essential in predicting the future evolution of the particular ecosystem to understand how the physical processes effecting the landscape, the watershed and its ecology have operated in the past.

Thus, improving your already strong monitoring systems is critical. Basic data are essential to any program and an increase in both the number of stations and duration of record will provide a firmer foundation for predicting the future. Perhaps this is the time to re-examine cooperative agreements with the U.S.G.S., Fish and Wildlife Service, etc. on adding to your network of stations.

Quality control is another nuts and bolts issue. I often learn of quality control problems in data collection and analysis the hard way -- when my witness is being cross-examined by the opposition. You could be that witness. As Aristotle said long ago, "Quality is not an act. It is a habit." You must imbue your staff, especially the young men and women right out of college or working during the summer, with the need for extreme care in the collection of your basic data. You all are probably used to peer review of your work, but that is nothing compared to the scrutiny your work will undergo by the opposition where money or a large water project is involved.

But those are just some of the nuts and bolts of any good program in the 21st Century. They are important. However, based on my work on the Forest Service case, I'm coming to the point I've really been leading up to -- one that is tremendously important in convincing the Court that your actions are truly in the public interest, and one that may provide a standard for your work here.

The Roots of a New Agenda - One Found in Past Traditions

In shaping your water resource program for the 21st Century, your "vision for the future," as Dr. Farrell so aptly termed it Monday afternoon, you must not forget your past. You in the Department of Agriculture have a proud tradition of caring for the land. It is in the past that the land ethic of the Department of Agriculture was forged. It is a reaffirmation of that ethic that may override parochial interests that each agency might have towards funding and allocation of personnel. And it is that ethic that will enable you to reach out to individuals in your sister agencies to get the best that science has to offer in solving the problem of shaping a water resource policy for the future.

Machiavelli stated, "Wise men say, and not without reason, that whoever wishes to foresee the future must consult the past." But as Will and Ariel Durant point out in The Lessons of History, "The future never just happened. It was created." That is what you are beginning this week, the creation of a strategy for the future that will protect our water resources for the benefit of all of the people in the 21st Century, and beyond.

One of the first research and technology transfers that ultimately led to the creation of the national forest system and had a significant impact on the development of a land ethic occurred with one man, George Perkins Marsh. It was during the latter half of the 19th Century that an understanding of and respect for nature and natural systems began to develop under his influence. He travelled to Europe as a diplomat, spoke 21 languages, and went to many nations in the Mediterranean basin where he began his studies of the effect of the mismanagement of watershed on the survival of civilization. He was an acute observer and when he returned to America he wrote a book, Man and Nature, published in 1864 and reprinted several times since.[8] In it he put forth the thesis that nature was not just to be exploited, but to be used and worked with. The "harmonies of nature," especially the balances of the natural world, were important economic tools. The society that disregarded them did so at its peril.

The entire formulation of federal forest reserve policy took place in the context of ending the American frontier, the ending of the assumption that the natural resources in the West were inexhaustible, the beginning of the Progressive Conservation Movement, and in the context of a mounting critique of an unrestrained free enterprise system in the exploitation of resources that often worked to the disadvantage of the common, or public good. A public consensus was formed that the natural resources were to be used wisely and in the national interest of all present and future users.

The influence of George Perkins Marsh on government thought and action in the late 19th and early 20th Centuries is pervasive, extending to the many people responsible for the establishment of the "Forest Reserves," Congress, and Presidents, including Cleveland and Theodore Roosevelt. Individuals who were influenced by Marsh include those who directed forest policy, legislation and the establishment of the forest reserves, including: Franklin Hough - first forestry agent in the Department of Agriculture in 1876; Bernard

Fernow, Chief of the Division of Forestry from 1886 to 1898; Gifford Pinchot, Chief of the Division of Forestry, later the Forest Service, from 1898 to 1910; Theodore Roosevelt, President of the United States from 1901 to 1909.

George Perkins Marsh was the fountainhead of the Conservation Movement. Up until Marsh, nature had generally been understood in this country as something to be conquered and exploited. Marsh called attention to the fact that human beings could adversely affect their environment and advocated that humankind should have respect for natural systems because the economic success of civilization depended on it.

Marsh cautioned against interfering with the "spontaneous arrangements of the organic or the inorganic world." If man interferes with the natural arrangement of nature, he should be very cautious to avoid the devastating environmental and economic consequences that could result.[9]

Marsh led a change in the United States from the attitude that nature was there to be exploited to an attitude that Americans should protect the processes, balances and harmonies existing in the natural world. Marsh understood that forests and watersheds are an interrelated system, not just the trees but the soils, rocks, stream flows, and stream channels all working together. Marsh's Man and Nature set the stage for the establishment of what became the national forests for the protection of favorable conditions of water flows.

Fernow, Chief of the Division of Forestry, understood the inter-relatedness of forest and water management. In his 1891 Report, transmitted to Congress, he noted continued problems of flooding and erosion, and the destruction of "favorable cultural conditions." He, too, took a holistic view, stating, "here it is that water management, and, in connection with it or as a part of it, forest management, should be studied; for without forest management no rational water management is possible".[10]

The U.S.G.S. viewed the watershed as an integrated, nested system, observing in its 14th Annual Report, "Not only the channels of streams but the valleys in which they run, the hills by which they are bounded, and indeed the entire surface represent the secular work of streams, and there is thus a marvelously harmonious interrelation of parts in each drainage basin."[11]

President Roosevelt withdrew large portions of the public domain for national forest reserves, including many of the forest lands on the east slope of the Rocky Mountains. As former governor of the State of New York, he knew of the Adirondack forest preserves the State had set aside in 1892 to protect water supplies. Roosevelt acted to provide long-term protection of national forests as natural reservoirs for the benefit of all the public. In a speech delivered to Congress in 1901, he stated, "The forest reserves should be set apart forever for the use and benefit of our people as a whole and not sacrificed to the short-sighted greed of a few . . . Forest conservation is . . . an essential condition of water conservation."[12]

Gifford Pinchot, the first Chief of the Forest Service, in 1905 wrote what became a part of the first book of regulations and instructions for use by forest officers in the field.

> The permanence of the resources of the reserves is therefore indispensable to continued prosperity, and the policy of this Department for their protection and use will invariably be guided by this fact, always bearing in mind that the conservative use of these resources in no way conflicts with their permanent value.
>
> . . . (W)here conflicting interests must be reconciled, the question will always be decided from the standpoint of the greatest good of the greatest number in the long run.[13]

In the 1907 book of regulations, Pinchot stressed the "wise use" of the natural resources in the forests, especially at the headwaters of the streams.[14]

I'm going to skip ahead now to someone with whom you all are familiar, one whose roots were in forestry and the Forest Service, and one whose vision was truly prophetic. In his last works, published just after his death in 1948, Aldo Leopold wrote several essays which represent the culmination of his environmental thinking, one of which is entitled "The Land Ethic."[15]

Aldo Leopold believed that a land ethic was simply the next step in the evolutionary development of an ethical system which first had dealt with the relation between individuals and next between the individual and society. Mr. Leopold declared that, "An ethic, ecologically, is a limitation on freedom of action in the struggle for existence." It provides a "mode of guidance for meeting ecological situations so new or intricate, or involving such deferred reactions, that the path of social expediency is not discernable to the average individual."[16] Isn't that just exactly the situation you are trying to address during this week?

According to Leopold, all ethics evolve from the premise that the individual, each of us included, is a member of a community of interdependent parts; we compete for a place in the community, but we

also cooperate so that there will be a place for us. A land ethic "simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land."[17]

Just as did Marsh, Fernow, Pinchot, and other conservationists before him, Leopold acknowledged that "a land ethic of course cannot prevent the alteration, management, and use of these 'resources', but it does affirm their right to continued existence, and, at least in spots, their continued existence in a natural state."[18]

What can you, each of you, do here in this short week? Well, this is but the beginning of your work. Each of you brings his or her own ecological conscience to this effort of defining a vision for the 21st Century. Aldo Leopold put it very well when he stated, "A land ethic, then reflects the existence of an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land. Health is the capacity of the land for self-renewal. Conservation is our effort to understand and preserve this capacity."[19]

In your area of water resource management, what is important is the preservation of "the integrity of the hydrologic continuum," sustaining the balance of "processes within the hydrologic cycle," as Dr. Luna Leopold recently stated.[20]

Collectively, you will be defining a program and an ethic for the 21st Century. What it will be only you can determine. In his last work before his death, which was a biographical tribute to a colleague in the Forest Service, C. K. Cooperrider, Leopold stated: "A new idea is, of course, never created by one individual alone. A prophet is one who recognizes the birth of an idea in the collective mind, and who defines and clarifies, with his life, its meanings and its implications." This statement was published in the same issue of the Journal of Wildlife Management that announced Aldo Leopold's own death in 1948.

From this conference and the meetings, work sessions, and efforts that will follow, one of you, perhaps several of you, will capture, or should I say "create," the "vision for the future," the ethic that will guide the management of the water resources of this country into the 21st Century. The gauntlet has come down to you from across the decades: Marsh, Fernow, Pinchot, Roosevelt, Leopold. You may be involved with the nuts and bolts of sediment transport, riparian habitat preservation, fisheries, watershed management, erosion control or water quality. Each of you has the opportunity to conduct his or her work in a manner that will pay honor to this rich tradition that is a continuing part of the fabric of the Department of Agriculture, that is, caring for the land. Marsh spoke for the 19th Century, Leopold for the 20th. Who among you will speak for the 21st Century?

Notes and References

1. Mr. Walch has tried a number of natural resource cases for the United States since joining the Department in 1971. He was lead counsel in the first trial, lasting 100 days, to quantify instream flow reserved rights claims of the Forest Service in a case involving the national forests of the Colorado Front Range. The views expressed are those of Mr. Walch and do not necessarily represent those of the Department of Justice.
2. Leopold, Luna B., "Ethos, Equity and the Water Resource," reprinted in Environment, Vol. 32, No. 2, March, 1990. On September 16, 1991, Dr. Leopold received the National Medal of Science from President Bush.
3. Dr. Leopold defined "hydrologic continuum" as "the effective operation of those forces in the drainage basin that maintain a balance among the processes of rock weathering, soil formation, water and sediment delivery to stream channels, and the exit of water and sediment from the basin. These forces are both biological and physical. For example, vegetation promotes weathering, soil formation and infiltration but mediates and modifies erosion and surface runoff." Ibid., at 19.
4. Act of June 4, 1897, 30 Stat. 34, 16 U.S.C. § 473, et seq.
5. Associate Chief, United States Forest Service, Washington, D.C.
6. Regional Forester, Region 2, United States Forest Service, Denver, Colorado.
7. Then Director, Watershed and Air Management, Forest Service, Washington, D.C. and now Regional Forester, Region 4, United States Forest Service, Ogden, Utah.
8. Marsh, George Perkins, Man and Nature or, Physical Geography as Modified by Human Action, 1864, reprinted 1965 (The John Harvard Library, Cambridge, Mass.).
9. For example, although Marsh believed that artificial storage reservoirs should be constructed, it should be done in such a manner as to work with the natural processes, the "harmonies of nature." Water

released from the reservoirs should be released into the stream channels in a natural way, to complement the naturally occurring flows.

10. U.S. Dept. of Agriculture, Report of the Chief of the Division of Forestry for 1891, pp. 194-195.
11. Fourteenth Annual Report of the Geological Survey to the Secretary of the Interior. 1892-93, Part II, p. 33.
12. "President Roosevelt's Message," The Forester, December 1901.
13. Use of the National Forest Reserves, Relations and Instructions, U.S. Dept. of Agriculture, Forest Service, 1905, p. 11.
14. The Use of the National Forests, U.S. Dept. of Agriculture, Forest Service, 1907.
15. Leopold, Aldo, The Land Ethic, in A Sand County Almanac, and Sketches Here and There" (Oxford Univ. Press, Special Commemorative ed. 1987).
16. Ibid., pp. 202-03.
17. Ibid., p. 204.
18. Ibid.
19. Ibid. p. 221.
20. Op. cit. nos. 2 and 3.

Water Resource Issues for the 21st Century: An Agricultural Research Service Perspective

J. van Schilfgaarde

The Agricultural Research Service (ARS) has a broad mission that encompasses most of the major research challenges confronting U.S. agriculture. The ARS strategic plan includes programs related to plant and animal productivity, human nutrition, the conversion of agricultural commodities into food and nonfood products, natural resource conservation and environmental quality. There are about 2,600 scientists in the agency and the gross funding for FY 1991 is $622 million. About $79 million of the agency's appropriated funds in the current fiscal year directly support research on Soil, Water and Air. Table 1 gives a breakdown of agency funding by major research objective. The agency's support for research on soil, water, and air has remained close to 12.7% of the total appropriated funds from 1986 through 1991. Close to 55% of these resources support research on water related problems.

ARS has been a major contributor to water resources research since the agency was formed in 1953. From 1953 until the major restructuring of ARS in 1972, research on water resources was conducted by the agency's Soil and Water Conservation Research Division. Prior to that time, research on agricultural water resources within USDA was conducted by the Soil Conservation Service. Since 1953, the number of ARS facilities engaged in water resources research has increased substantially. At the present time, water related research is conducted at 54 locations in more than 30 states. If the locations that contribute to water quality research through work on weed control, pesticide application technology, biological pest control, and integrated pest management are included, the number of locations and states that participate increases to 69 and 34 respectively. Clearly, ARS is making a major commitment to the solution of the nation's water resources problems. As of July 12, the level of funding for water related research at the project level was about $46 million.

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How are these resources being used? Some insight can be gained from the way in which this research is perceived and coded by ARS scientists. The project documentation system used in ARS allows all scientists to classify their work using water codes developed in 1966 by the Committee on Water Resources Research (COWRR). Although this committee was abolished in the fall of 1977, the COWRR coding system is still used by most, if not all, federal agencies.

Table 2 shows the current levels of funding for these water related activities in ARS. Close to 98% of the research is related to components of the hydrologic cycle, water supply augmentation, water quantity management, and water quality management. A breakdown of ARS research on the hydrologic cycle (see Table 3) shows that less than 10% of the work is directed toward the complete cycle. The major effort is directed toward improvements in our knowledge of processes and specific components of the water cycle, with erosion and sedimentation, water in soils, and water and plants receiving most of the funds. Research on streamflows and large water bodies, such as lakes and estuaries, is a minor component of the current program.

Research Priorities in ARS

1. Water Quality

ARS has maintained a major research effort in water quality assessment and protection for more than two decades. During this time, ARS scientists have made a number of significant contributions to the total national effort on water quality. There is general agreement that this national effort has materially improved the quality of the nation's water resources. Nonetheless, widespread concern still exists within the U.S. community that more needs to be done to protect both the food supply and the environment from degradation by agricultural activities. As long as these real or perceived threats to human health and the environment are not adequately addressed through research, education, and technical assistance

programs, public concern about the state of the environment will persist.

The July 1991 issue of the journal "Agricultural Engineering" includes an article by Jack King entitled "A Matter of Public Confidence". The article focuses on the results of a survey conducted by the American Farm Bureau in 1990 on the public's attitudes and perceptions regarding food safety, agricultural chemicals and their on-farm use. The Farm Bureau's survey showed that more consumers (89 percent) are concerned about pesticide residues in food than any other food quality issue. This fear of chemicals, even though difficult to justify on a scientific basis, spills over into the community's attitude toward environmental degradation by chemicals.

Community anxiety about the quality of the nation's drinking water supplies is heightened by the growing evidence that much of the continuing degradation of the nation's water resources can be attributed to nonpoint sources of pollution, with agricultural activities identified as a major contributor. In turn, this concern is translated through the political process into agency and departmental agendas that promote water quality protection as a high national priority. As a direct consequence of increased political support, research on water quality in ARS has been expanded in recent years from about $25 million in 1988 to more than $45 million in 1991. Research on water quality management is now the most strongly supported water related research activity in ARS, and is likely to remain so for at least the next five years.

At the present time, much of ARS's research on water quality is directed toward reducing the potential for water contamination by agricultural chemicals. A smaller, but still substantial, effort is being made to control water quality degradation by other contaminants, such as sediments, salts and toxic elements. The current research agenda is primarily farm oriented, and focuses on the development and promotion of farming practices and systems that improve both water quality and the efficiency of chemical use. The farming practices that are being evaluated include: adjustments to the timing, placement, and rates of application of chemicals, new pesticide formulations, changes in crop rotations, tillage, drainage, and irrigation water management, and the expanded use of nonchemical alternatives for controlling plant pests.

Because the current work is largely field based, only limited attention is being given to assessing and controlling the off-site effects of agricultural production systems. One major component of the ARS experimental program on water quality that will be conducted on a watershed scale is the recently funded MSEA (Management Systems Evaluation Areas) project. Information on the off-site effects of corn and soybean farming systems will be obtained for 10 sites in the Midwest. However, it will be some time before the experimental data from these sites will permit objective conclusions to be reached on off-site effects. Even then, it will add only peripherally to our knowledge of the fate and transport of contaminants in streams, rivers, and larger water bodies. ARS is also collaborating, through scientist involvement and limited financial support, with SCS and ES in a water quality demonstration program and a hydrologic unit studies program that jointly constitute the primary contribution of these two agencies to the Presidential Initiative on water quality. ARS will explore opportunities to strengthen its support for the SCS/ES programs, and, depending on the success of future funding initiatives, will expand its water quality activities to other parts of the country.

Is the present ARS program adequate in scope and vision to serve the needs of the farm community, USDA, and the nation? This issue needs to be addressed by the water quality work group. Some insight into how others view the progress that has been made and the deficiencies of current water quality programs can be gained from the June 1991 Interim Report by the Member Organizations of Water Quality 2000 entitled "Challenges for the Future". The findings in the report are implicitly supportive of the ARS agenda. Many of the information related impediments to water quality protection identified by the Agriculture Work Group are being addressed by ARS research. However, a few are not. For example, the Work Group found that "Sediment from agriculture and other nonpoint sources accounted for 42 percent of the impaired river miles, nutrients for 26 percent, while pesticides accounted for 10 percent", and that "Economic studies place the cost of sediment damages in the billions of dollars per year". ARS has maintained a major research effort on landscape erosion control and has successfully demonstrated the benefits of reduced tillage in controlling sediment releases to rivers, lakes, and estuaries. However, other major sources of sediments have received less than adequate support. For example, the financial and human resources available in ARS for research on gully and channel erosion and control has decreased

substantially, even though in some areas, such as the Yazoo River Basin in Mississippi, this is the dominant source of stream sediments.

One of the central issues that needs to be addressed by all the work groups at this workshop is the scale at which natural resources programs ought to be conducted. Because implementation of much of the new science and technology that is developed by ARS research directly benefits the individual farmer, field scale research will continue to be a dominant component of the ARS program. Nevertheless, the projected loss of rural representation in the Congress, and the continued strength of the environmental movement should provide enough incentive for us to give more attention to the broader natural resource concerns of our urban community. What is the role of ARS and USDA in protecting aquatic ecosystems and habitats? How great is the risk that too narrow a perspective on the strategies to be used in solving water quality problems will prove suboptimal, and perhaps lead to ineffective or unnecessary protection measures?

Finally, and perhaps as crucial as any water quality issue or concern that I have touched on, is the future role and function of ARS and USDA in water quantity research and management . Can USDA afford to be complacent about the water quantity challenges of the next few decades? What effect will our changes in farming practices and systems have on water yields, peak stream flows, and low flows? Are we satisfied with what has been cone to mitigate the effects of droughts and floods? For the present, our water resources agenda is dominated by community concern for the quality of the environment. As the more serious of these problems are solved, and the perceived problems are addressed through effective assessment and educational programs, changes in societal priorities are inevitable.

2. Climate Change

There has been a major effort at the national level to respond to increasing concern within the global community about the potential for significant climate change as a direct result of projected increases in the concentrations of thermal gases, such as carbon dioxide, in the earth's atmosphere. While most of the current federal funding for research related to climate change is being directed toward improving the reliability of climate change forecasts through improvements in General Circulation Models (GCMs), future priorities will include assessments of economic and environmental impact. There is wide recognition and acceptance that even marginal changes in climate will have major consequences for water resources; food, fiber, and timber production; coastal areas; and most terrestrial ecosystems.

ARS has received modest increases in funding for global change research during the past two years. The potential for major appropriations in future years remains uncertain. However, as the GCM forecasts are improved and the consequences of the projected effects of climate change on society can be established with greater confidence, a clearer picture of the magnitude of the problems to be solved and the resources needed to address them will emerge.

Some of the early analyses of the potential impact of climate change on the nation's water resources projected major reductions in the average annual flows of the Colorado and Rio Grande rivers. While the analyses are flawed, and the predictions based on current knowledge uncertain, reductions of 20% to 40% in the annual flows of rivers, such as the Colorado and Rio Grande, would place enormous pressure on the water resources of the West and Southwest, and force substantial reductions in irrigated agriculture.

The implications for specific irrigated areas, such as California's Central Valley, are likely to remain unknown for some time because of the difficulty of assessing the effects of climate change at watershed and sub-basin scales. However, even without taking into consideration major climate change, the present five year drought in that State has already added an element of urgency to the debate on California's water allocations and regulations.

An analysis of the effects of the drought in California, reported on in July, 1991, by the Washington Post, refers to a major depletion of fish and wildlife populations in California's Central Valley, with federal water managers envisioning a potential "nightmare - a federal court takeover of the nation's largest water project under authority of endangered species laws". As indicated in the newspaper's report, this would be "an environmental godsend and a farmer's catastrophe: Much of the water now used to irrigate the state's vast croplands would be returned to its natural course, through parched rivers and dry marshes to the sea". The article concludes with a suggestion from one of the wildlife managers in the Bureau of Reclamation that "the bureau has yet to address the fundamental problem: breaking agriculture's stranglehold on California's limited water

supplies".

The situation in California merely highlights the vulnerability of agriculture to a major reduction in water supplies. If the global change projections for western water resources are borne out, the challenges for agriculture will be enormous. Similar scenarios can be developed for other regions of the country such as the Great Plains States. The efficiency with which precipitation is converted into biomass is affected by temperature, with the efficiency in the cooler northern latitudes being almost twice the efficiency found in southern latitudes. Increases in average annual temperatures of the magnitude projected by some GCM's would be expected to reduce quite substantially the productivity of all parts of the Great Plains with the most dramatic decreases occurring in northern latitudes. The adverse temperature effects will be offset by increased water-use efficiency at higher carbon dioxide levels and possibly by enhanced precipitation in some crop growing areas. However, some models also predict a decrease in precipitation for land areas far removed from coastal influences which would exacerbate the Great Plains problem.

Perhaps one of the core issues that might be considered by the workshop participants is the sensitivity of the resources in the different crop, animal, and timber producing regions of the country to changes in temperature and precipitation. While the positive effects of increased carbon dioxide in the atmosphere on certain plant functions, including photosynthesis and stomatal responses, are will established, little is known about the effects of water and temperature stress on plant performance in a carbon dioxide enriched environment. Furthermore, the effects of major changes in the growth of vegetation in natural and managed ecosystems on key components of the hydrologic cycle and on a region's water resources is even less well understood.

More general questions that might be considered include: What role should USDA have in promoting an improved understanding of climate change resulting from an increase in the atmospheric concentrations of greenhouse gases? What is an appropriate USDA response to international initiatives, such as the Global Energy and Water Cycle Experiment (GEWEX)? Is a major role for USDA critical to the success of these initiatives? Does USDA have some unique disciplinary strengths, data bases, and facilities that could materially contribute to the solution of global change problems? Could these USDA strengths be integrated successfully into national and international global change programs? Should they be? What strategies offer the most promise?

3. Wetlands and Riparian Zones

The ARS research program on wetlands and riparian zones, though productive and instructive, has not attracted a high level of internal support. Much of the work that has been done during the past decade needed internal redirection of resources to support ATS scientist initiatives. In the absence of a clear and unambiguous national policy, there is limited interest in supporting research of these ecosystems. More recently, as a result of farm and environmental legislation and executive policies on wetlands, there has been a growing awareness of the value of these ecosystems and the need for providing them greater protection. The important role that riparian zones have in removing plant nutrients from surface water and shallow groundwater has been recognized for some time and ARS has made several significant contributions to our present knowledge of their effectiveness in maintaining surface water quality. Even so, major knowledge gaps remain. For example, the capacity of riparian zones to reduce the potential contamination of surface waters by pesticides is unknown.

Despite strong expressions of support at the national level, the issue of wetland protection remains buried in controversy. Until current disagreements on the extent of the protection that is needed are resolved, it is unlikely that ARS will be in a position to support a major research effort aimed at protecting existing wetlands from farming operations. One of the key areas of disagreement that has not been resolved at the federal level, but that is still not accepted by several outside interest groups, is the definition of what constitutes a wetland. ATS will, of course, continue to be responsive to requests from the Soil Conservation Service and other action agencies for assistance in developing guidelines for managing wetlands, restoring degraded wetlands and creating artificial wetlands. Wetland research offers many challenges and opportunities to the research community. For example, in summarizing current limitations on research and development, the Water Quality - 2000 report concludes that "It remains unclear whether the creation or restoration of wetlands is technically or scientifically feasible".

With a clearer statement of current national

policy relating to wetland protection, and improved guidance on federal and departmental roles, the work group would be in a stronger position to establish a direction for future work on the management, restoration, and protection of wetland ecosystems. I would suggest that the work group focus on the scientific and technical challenges that a wetland program will face and structure their recommendations in terms of overall societal benefits. The following quotation from the Water Quality - 2000 report might help: "Our tendency, as a society, is to underestimate the cost of pollution in currently less populated areas, such as wilderness and aquifer recharge areas, because there are fewer immediately measurable impacts on human health and because we tend to undervalue the impacts on biological communities and their habitats".

Part of the challenge for the work group will be to determine how we might improve our understanding of the risks and costs we face in accepting a continued loss of wetlands, and conveying a clear picture of these risks to legislators, farmers, and the general public.

4. Instream Flows and Channel Modification

The ARS program on instream flows and channel modifications has also been reduced dramatically in the past two decades. ARS has closed down major instrumented watersheds in Danville, VT, and Santa Rosa, NM, and has reduced streamflow measurements at watersheds in Oklahoma, Texas, Georgia, and Pennsylvania. As indicated in an earlier table, funding specifically directed toward research on streamflow is currently below $0.3 million annually. Research aimed at maintaining instream flows for aquatic habitat protection has never been a major ARS activity, although there is significant interest at some ARS facilities, such as the National Sedimentation Laboratory at Oxford, MS, in evaluating the effects of watershed management on aquatic ecology.

ARS research on channel modification is also largely centered at Oxford, MS. Of major interest is the development and evaluation of instream structures to maintain channel integrity, and reduce excessive sediment transport in the Yazoo Basin. Earlier research in Oklahoma on the long-term effects of conservation practices on channel morphology has been discontinued.

In summary, the major thrust of the current ARS research program in water resources is directed toward water quality management, and this situation is likely to continue for some time. The merits of expanding the research to include the fate and transport of chemicals and other contaminants in streams, lakes, and estuaries need to be assessed. ARS will also continue to promote aggressively an expanded program in global climate change that will affect several ARS facilities in states west of the Mississippi. A strong case can be made for supporting a major initiative by the department on global climate change, and this action warrants serious consideration by all three natural resource agencies. Depending on the success of budget initiatives in the next few years, the ARS program could be expanded to include several locations in the Mississippi River Basin, and ultimately could be extended nation-wide. There is significant potential in ARS to expand the current limited work on wetlands and riparian zones, which could have major benefits for wildlife preservation and large area water quality management. A major strengthening of the current ARS research program on instream flows and channel modification will require stronger expressions of urgency and need by action agencies. The strong support that local communities, SCS, and the Corps of Engineers is providing research on channel stabilization and sediment yield reduction in the Yazoo Basin of Mississippi is largely responsible for the high level of effort at the ARS National Sedimentation Laboratory.

TABLE 1

RESEARCH OBJECTIVE	CURRENT GROSS FUNDING $ MILLION
Soil, Water and Air	79
Plant Productivity	239
Animal Productivity	111
Commodity Conversion and Delivery	113
Human Nutrition and Well-Being	54
Systems Integration	26
TOTAL	622

TABLE 2
WATER RESOURCES RESEARCH

RESEARCH ACTIVITY	FUNDING ($000)
1. Nature of Water	0
2. Water Cycle	24,463
3. Water Supply/Augmentation	5,185
4. Water Quantity Management	5,985
5. Water Quality Management	9,320
6. Water Resource Planning	78
7. Water Resources Data	349
8. Water Structures Engineering	505
TOTAL	45,885

TABLE 3 - WATER CYCLE

DESCRIPTION	FUNDING ($000)
1. Water Cycle	1,888
2. Precipitation	893
3. Snow, Ice, Frost	1,036
4. Evaporation and Transpiration	2,861
5. Stream Flow	247
6. Groundwater	2,000
7. Water in Soils	4,739
8. Lakes	352
9. Water and Plants	4,499
10. Erosion and Sedimentation	4,924
11. Chemical Processes - Water	1,024
TOTAL	24,463

Water Resource Issues in the 21st Century: A Forest Service Research Perspective

Jerry A. Sesco

During the past two days you have heard some very specific presentations on water resource issues. It is critical that we understand these issues as we look forward to the 1990's and beyond. This was evident in a recent article in the New Scientist that stated, "...the politics of water will become as important as the politics of oil...." In the United States we know that water quality is a major environmental issue. In a 1989 Harris poll, 76 percent of those Americans questioned believe that a good job has not been done to keep our lakes and rivers clean. Obviously, water will be at the center of many land use issues to be faced by public land managers and private land owners alike. Meetings such as this are important planning efforts. The Agricultural Research Service and Forest Service Research need the input and support of primary users if we are to plan research to meet information needs.

As you know, the Forest Service has a long history of leadership in water resources research and management. This year, 1991, marks our centennial year. It was in 1891 that Congress established the first of the forest reserves. These lands soon would become the early entries in the National Forest System. Later in 1897, the Organic Act directed the emerging agency to "...maintain favorable conditions of water flow..." as one of its fundamental responsibilities. More recently, the Renewable Resources Planning Act of 1974 directed the Agency to increase its planning efforts. The latest RPA Assessment, as it is called, identified water resource issues as "...high priority research areas...."

For the moment, however, I would like to step back from the specifics of the issues you are debating and place our water related research needs in the larger framework of the ecosystem. Within the Forest Service we are involved in a major effort to align our research programs with ecosystem level planning and thinking. This is not entirely new to us, elements of our watershed research program have been national leaders in ecosystem studies for many years. Many of you are familiar with the legacy of the Coweeta Hydrologic Laboratory in North Carolina, the Hubbard Brook Experimental Forest in New Hampshire, and the H.J. Andrews Experimental Forest in Oregon. That legacy represents over 50 years of long-term watershed research. We probably have more detailed ecosystem level information available at those three sites than at any other forested location in the North America. All three are part of the National Science Foundation's Long-Term Ecological Research program. I am certain that the success of the LTER program and Forest Service contributions to it, have had a major influence on the content of two recent reports by the National Research Council. Both reports are important to your efforts this week.

The first report is titled, "Forestry Research: A Mandate for Change," released in 1990. The following is a quote from the executive summary. "Although concern about and interest in the global role and fate of forests are currently great, the existing level of knowledge about forests is inadequate to develop sound forest-management policies. Current knowledge and patterns of research will not result in sufficiently accurate predictions of the consequences of potentially harmful influences on forests... To help overcome this unfortunate deficiency in knowledge, a new research paradigm will need to be adopted--an environmental paradigm. Even though previous approaches to forestry research employing the conservation and preservation paradigms have been adequate to meet many past forest management goals, they are now inadequate to guide forestry research in the future."

Within the body of the report, the notion of an "environmental paradigm" is elucidated. In short it refers to a new orientation--away from simple production and toward recognition of the multiple values of forest environments. It is significant for you this week to note the differences between forestry and agriculture in your deliberations, but

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it is also significant to recognize the common ground. The NRC report recognizes our shared scientific roots in botany, zoology, soil science, genetics, mycology, plant physiology and pathology, entomology, ecology, microbiology, and statistics. The report also notes that the flow of ideas has been largely from agriculture to forestry. The critical differences are that forests are managed over long time periods with harvests measured in decades while agriculture harvests are usually annual events. Although a flow of ideas may have been adequate in the past it is no longer adequate for the future. We need to link forestry and agriculture in an holistic way, and water is certainly a common link.

The second NRC report is titled, "Opportunities in the Hydrologic Sciences" released in 1991. The report states: "While we have spent lavishly to cope with the scarcities and excesses of water and to ensure its potability, we have invested relatively little in the basic science underlying water's other roles in the planetary mechanisms. ...The supporting scientific infrastructure, including distinct educational programs, research grant programs, and research institutions, does not now exist for hydrologic science and must now be put in place."

As with the NRC report on forestry research, this report emphasizes the importance of increasing the geographic scale of our scientific investigations and lists several unsolved problems. Notably:

"How do we aggregate the dynamic behavior of hydrologic processes at various space and time scales in the presence of great natural heterogeneity?"

"We need improved understanding of stream channel integrity, including the development of a consistent spatially and temporally correct definition."

"What can the soil, sediment, vegetation, and stream network geometry tell us about river basin history and about the expected hydrologic response to future climate change?"

"What is the nature of the feedback processes that occur between biochemical processes and the various physical transport mechanisms in the soil?"

These questions and others listed in the report, emphasize the need for cooperative research programs among agencies in USDA and in the Federal Government at large. The report emphasizes the close linkage of ecosystems and the hydrologic cycle, and notes that understanding these interactions is essential to interpreting, forecasting, and even ameliorating global climate change.

Both NRC reports strongly support the course Forest Service Research has taken as described by our strategic plan, "Strategy for the 90's for Forest Service Research." The plan identifies three major components with associated areas of emphasis. Two of those components are closely linked to the issues before this workshop.

1. Understanding Ecosystems-Includes ecological processes, global change, atmospheric deposition, surface, ground and water pollution.
2. Understanding and Expanding Resource Options-Includes systems and practices suitable for production and use of natural resources, with increasing emphasis on water, fish, wildlife, and recreation.

Throughout all programs, there is a need to work closely with cooperators, be more global in scope, and use a more multidisciplinary approach to organizing and carrying out research. Obviously we cannot do this kind of research in a vacuum. We need to strengthen our cooperative efforts with others and what better place to start than within the Department of Agriculture. I share your interest in working toward a common understanding of issues and identification of opportunities to effectively address these large scale issues.

Let me share with you a few observations on the four issue areas that you have focused on this week.

Wetland-Riparian

We are reminded of the importance and value of wetlands every day in Washington--between editorials decrying local land development, or the constraints on land development, articles on revisions of the Federal manual, and hearing testimony on the Hill regarding wetlands legislation. In recognition of the magnitude of wetland issues, Chief Dale Robertson has identified "Wetlands" as a National Research Problem for FY 1993. Just last week, scientists and managers from all of our research stations met to identify research priorities for 1993 and beyond. Of greatest concern are the impacts of management on wetland functions and values, particularly in southern forested wetlands and in riparian areas in the West. We are also continuing our long-term research in the northern peatlands at a landscape scale. A constant theme for all systems is to develop the knowledge and techniques to maintain, restore or enhance wetland functions and values.

In all areas, cooperation with other agencies, especially SCS, COE (Corps of Engineers), EPA and F&WS, and institutions is a high priority. Most recently, scientists from the Forest Service and F&WS have joined to develop a research project across the South. This study will incorporate a series of research sites with common protocols to evaluate resource management impacts, whether the resource is wildlife, water, timber--or conservation of biological diversity.

In response to the rising interest in wetlands, I recently established the National Wetlands Specialist position held by Ann Bartuska. Ann has described our plans for an expanded research effort.

Water Quantity and Quality

We have been studying water quantity since about 1908 when the famous Wagon Wheel Gap project was initiated. More recently we have emphasized water quality. Today we need to address water quantity and quality at a larger scale than what we have previously dealt with in the Forest Service. As Ed Corbett from the Northeastern Station has described, our scientists need to quantify the cumulative effects of moving water, nutrients, toxic chemicals and sediment through watersheds and evaluate the cumulative impacts on end users..humans and the biological community. Thus we need to know the pathways and rate of water flow within watersheds as water is the medium of transport for sediment, nutrients, and pollutants.

Regulators and land mangers are asking some tough questions:

Are "Best Management Practices" (BMPs') doing the job they are designed to do?

Are BMP's adequately defined?

Is the Total Maximum Daily Load concept used by EPA for point source pollution useful in non-point source management?

Regardless of the answers to these questions, we must improve our ability to transfer research results to large landscapes if managers are to meet environmental quality standards and production goals.

Instream Flow/Channel Maintenance

Instream flow and stream channel maintenance are closely related to my earlier reference to the Organic Act of 1897 and our responsibility to maintain favorable conditions of flow. Chuck Troendle from the Rocky Mountain Station has discussed the need for additional research. For example: We need better characterization of the physical and biological thresholds of stability in streams; we need to know the limits of "acceptable change" with regard to physical and biological properties; and, we need improved understanding of stream channel integrity including the development of a consistent spacially and temporally correct definition.

In an effort to improve overall management of streams on the National Forests, we are establishing a Stream Systems Technology Center at the Rocky Mountain Forest and Range Experiment Station in Fort Collins, Colorado. This team of specialists will strengthen the link between land managers and research on this important topic.

Global Change

Doug Fox of the Rocky Mountain Station has made it clear that global change is not just climate change but involves the heavy hand of humans on the landscape.

Global change and water resources are very closely linked. Climate change is driven by changes in the global hydrologic cycle. While the Forest Service global change research components are atmosphere-biosphere interactions, disturbance ecology, ecosystem dynamics and human interactions, the bottom line is how will global change affect us and should we do anything about it. Put in water terms.

How much water will be available, and how will we manage it?

The Colorado River is a good example of where we have erred by not using the best possible information when apportioning flow to users. Further, conflicts between agricultural use of water and urban use have been aggravated by early decisions on where to locate cities. No one in their right mind would put Phoenix where it is today, but it was done. Now, how will Phoenix get whatever water it needs? People have chosen to live out of harmony with semiarid landscapes all over the world. Natural resource managers recognize the problems and we have the responsibility to find solutions.

Our global change program will try to do this by looking at ecosystems and landscapes across scales, by integrating work going on at many locations and by developing "corporate" water-related outputs. Doug has identified that a primary output from the Global Change program will be a framework for terrestrial ecosystem modeling. To meet our

global change commitment, we have instituted a novel management structure for Forest Service Research that includes 5 regional Program Managers coordinated by Dr. Elvia Niebla in the Washington Office. In Global Change, perhaps more than in any other area, it is clear that we cannot accomplish our objectives without substantive partnership with ARS and other members of the CEES Global Change community. Thus, while your research will remain as important to your local customers and your scientific peers as it has ever been, we now have an added client, those scientists and policy makers trying to develop prudent alternatives for the human habitation of the Earth.

Work hard the next few days. Give research administrators a product they can use, and give the Department a product they can be proud of.

Water Resource Issues for the 21st Century: A National Forest Service System Perspective

Al Schacht and Dave Unger

Water is becoming one of the most important resources we manage. There is an increasing awareness of water resource issues by the American public and by Congress.

Without doubt, the water resource will become of greater and greater importance in the future, both in terms of quantity and quality. For example, Congress has begun deliberation of reauthorization of the Clean Water Act (CWA). This Act is already a technically complex piece of legislation. The new Act will likely be more so. There is interest in tightening State controls on nonpoint sources of pollution. This will have a major impact on the way in which we do business. Because water is a State responsibility as defined by the CWA, federal agencies must comply with State requirements. State programs include land use requirements, as well as how we conduct land management practices, i.e., BMP's.

Under existing CWA legislation, EPA is issuing Storm Water Discharge Regulation that may require permits on activities not permitted before. Compliance will be technically complex. EPA is continuing to bring existing nonpoint sources under the point source permit program. The point source program is more attractive to EPA because it is a required regulatory program.

Congress enacted a Coastal Zone Management Act last November. It identifies a State program for control of activities that cause nonpoint source pollution, and that impacts the coastal zone and coastal zone resources. This could result in a redefinition of Coastal Zone boundaries to the uplands. It will require the development of management measures under a regulatory program.

Congress continues to consider legislation for the protection of wetlands. There will be increasing competition for water in water short areas. We will be involved in issues related to water rights litigation and conditioning of special use permits to protect the federal interest. The Clean Water Act contains provisions related to acid rain and the impact on the surface and subsurface water resource.

There are many more issues, but without listing more, it is evident that there is a lot of interest in water resources and we can expect an increased interest in our programs department wide. We can also expect that new legislation will become more technically complex.

Meeting our responsibilities for water resource management on the 191 million acres of National Forest System land, providing assistance to the States on matters related to forest management on State and private forest lands, and conducting necessary research will be a major challenge for the Forest Service in the future.

The Forest Service is responsible for the management of the headwaters for many of the major river systems in this country. These lands will increase in importance because of their high quality water. The Forest Service provides technical and financial assistance to State foresters to protect or improve soil fertility on non-federal forest lands and to improve the quality, quantity, and timing of water yields. The Forest Service is a recognized leader in forest management throughout the nation and world. This includes the impact of forest management practices on the water resource.

The Forest Service has just instituted a new Deputy Area for International Forestry. This will increase our responsibility for forestry and water related resources world wide. The Forest Service has been delegated USDA responsibility for providing national leadership in forestry and in conducting research on a broad range of forestry issues.

Because Forest Service responsibilities are truly global in scope, and with the increasing importance of water, the work that you charted for this workshop is of extreme importance. As I understand it, you are to determine a "vision" for the future direction of USDA water resource programs. I can think of no more important task.

Let me just mention a few activities and programs related to water resources that the Forest Service is involved with. We have taken a

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Authored by Dave Unger, Associate Deputy Chief, National Forest System, presented by Al Schacht, Associate Deputy Chief, State and Private Forestry, Washington, D.C. 20250

lead role in development of a workable nonpoint source strategy that applies not only to forested lands, but also to agricultural lands. This program emphasizes prevention of problems through design of management practices that can be expected to minimize impact on the water resource. These designed practices are put into place and then monitored to ensure they perform as expected. If they do not, design criteria are changed for future operations, and mitigation implemented to correct unforeseen problems that may have been created.

We have a new riparian strategy directed toward improved management of the sensitive stream corridor and areas adjacent to perennial bodies of water. This strategy will assist our line officers in managing these sensitive areas.

We are continuing an aggressive watershed improvement program to improve lands that have suffered past abuse. In addition to the use of vegetation for stabilization, we are looking at a program based on an understanding of geomorphic considerations.

We are refocusing our attention to our primary responsibility to provide for "favorable conditions of water flow" as provided for in our Organic Act. We have determined that in order to provide for favorable conditions of water flow, we must provide for the long term protection of the watershed. Other uses will have to be compatible with this responsibility. Successful institution of these programs will require the best we have in technical expertise, and will require extensive technical information. We will almost certainly need more research to answer known questions, as well as, additional questions that will be raised in the future. To ensure that this research is applied, we will need to give increased attention to training of our specialists and to recruitment of technical personnel.

This workshop effort is an important step in improving and strengthening interagency cooperation within the Department of Agriculture. While the Forest Service has the expertise and responsibility for water resource programs for forestry related programs, much of the technology we use could be of value to other agencies within the Department. Likewise, technology developed by other agencies is, and will be of value to the Forest Service. For this reason alone, your emphasis on interagency cooperation is vitally important.

We can be much more effective by making sure that barriers to cooperation between our respective agencies are identified and removed. Your efforts here in this workshop are on target. I will you success in this workshop. The results of this workshop could help shape the future direction of the Forest Service of the Department.

Water Resource Issues for the 21st Century: University Activities

Neil S. Grigg

Introduction

United States universities have been active in water resources research and education for many years. Since the drought of the 1950's activity has increased, including the organization of State Water Research Institutes and the Universities Council on Water Resources. Currently, research and education activity is quite high among the universities in the four topics of this workshop: wetland and riparian issues; water quantity and quality; instream flows and channel maintenance; and global change.

In the 1960's a farsighted group of academics realized that the universities have much to contribute to the field of water resources, especially to the interdisciplinary integration of knowledge. They created an organization called the Universities Council on Hydrology, which later evolved into the Universities Council on Water Resources (UCOWR). It retains its interdisciplinary focus and carries out its activities mainly through committees, annual meeting projects and a newsletter.

One of UCOWR's committees, the Research Committee, has undertaken an active program of seeking methods to coordinate water resources research and education nationwide. Several meetings have been held involving federal agencies, the private sector, universities and nonprofit organizations. The focus is on developing an ad hoc coalition approach to research coordination, research planning, education, and advocacy for the National Water Resources Research Program.

The 1950's national drought also was the impetus for developing the water resources research act, which included the establishment of a Water Resources Research Institute (WRRI) in each of the states and territories. The Water Resources Research Act was passed as P.L. 88-379 in 1964 and has been reauthorized several times, most recently through 1995 with P.L. 101-397. The WRRIs conduct programs of research, technology transfer, and graduate training within their individual states. Emphasis is on intergovernmental coordination to ensure maximum effectiveness in the transfer of knowledge between agencies and organizations involved in water resources management. Federal support for the institutes comes through Section 104 of the Water Resources Research Act. Section 105 of the Act provides for matching grants to institutes and other qualified organizations for research on problems of national interest. The federal managing agency for the Water Resources Research Act is the U.S. Geological Survey. It is interesting to note that the water problems of the 1950's that led to the creation of the WRRIs focused on drought and water shortage. Today the interdisciplinary focus of the research carried out through the WRRIs has enabled an integration of knowledge that allows complex ecological, political, sociological and management problems to be addressed as well as hydrologic problems related to water development.

The water resources research institutes are coordinated through the National Association of Water Institute Directors (NAWID). Examples of WRRI program accomplishments cited by NAWID include projects on conjunctive management of surface and groundwater, conservation of water in irrigated agriculture, removing obstacles to fish migration, and acid deposition. These are but a few examples of research projects completed by the institutes.

Regional Collaboration - The Colorado River Basin

With water problems becoming more complex, especially on a regional basis, there is a tendency for institutes to cooperate in research and other programs. As this meeting is held in Denver, it seems appropriate to cite the Colorado River Basin as an example of regional cooperation. Seven states make up the region: Arizona;

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California; Colorado; Nevada; New Mexico; Utah and Wyoming. The institutes in these states have come together in an organization called the Consortium of Water Institutes and Centers (CWIC) and are now exploring the feasibility of forming a new consortium, The Powell Consortium for Water Resources Research and Education.

Each institute contributes its own unique focus to the Consortium which can be illustrated by some examples. Naturally, in Arizona arid-lands hydrology is of interest, but the institute focuses as well on forestry and water resources. California, being a large state, has a program that includes an average of about 40 projects statewide. It also operates a unique water resources archives with over 100,000 titles. The Colorado Institute focuses on cooperation with water users, sponsors an annual water management conference, and includes a program of about 10 research projects annually. In Nevada, the focus is on groundwater development and management and waste management. New Mexico features cooperative projects as well as normal institute activities and boasts a continuing series of annual conferences for the last 36 years. Utah carries out its research through the Utah Water Research Laboratory. It has a large, multidisciplinary program with considerable international activity including an international education program. Wyoming has an active program of research including the topics discussed at this workshop. Some of its unique programs include a water resources data base and an annual teachers' workshop in water resources.

The Powell Consortium Institutes have conducted regional projects on water transfers and severe, sustainable drought and new programs in waste management and global climate change are in the planning stages.

WETLANDS AND RIPARIAN

Issue Session

Status of Wetlands and Riparian Program: Agricultural Research Service

F. Douglas Shields, Jr. and Charles M. Cooper

The Agency

The Agricultural Research Service (ARS) is the principal USDA intramural research agency and represents a significant fraction of the national agricultural research capability. ARS employs about 2,600 scientists at 122 US locations and seven overseas laboratories and has an FY91 budget of $624 million. About $77 million of the FY91 funds were budgeted for research on natural resources and the environment including about $29 million for water quality research. An additional $78 million was budgeted for work in sustainable agriculture (Anonymous, 1991).

Relevant Policy

The ARS mission includes development of technology needed to insure maintenance of environmental quality and natural resources. Furthermore, the ARS provides research and development to support implementation of federal agriculture legislation. The Food, Agriculture, Conservation and Trade Act of 1990 (1990 Farm Bill) contains provisions dealing with delineation, conversion, and restoration of wetlands. The act extended the Conservation Reserve Program and set up a Wetlands Reserve Program, both of which encompass set-aside of riparian zones under certain circumstances (Cohen et al., 1991). In addition, the act established a water quality and nutrient management research program within the USDA, which could indirectly involve ARS work in riparian zone and wetland topics. A specific role for ARS in the new research program was not prescribed.

The current (1992-1998) ARS program plan (US Department of Agriculture, 1991) includes objectives dealing with soil, water, and air conservation and development of new agricultural practices and systems, but is silent on wetland and riparian zone issues. In general, agency policy mandates development of technology to support implementation of existing soil and water conservation legislation. The current ARS plan indicates that new agricultural systems will be developed to reduce impacts on fish and wildlife habitats, and that effects of agricultural drainage on "lakes, streams, and adjoining habitats will be considered in terms of use and protection of public lands."

Existing Program - Overview

While elements of many ongoing ARS projects may ultimately provide basic knowledge useful in understanding wetlands and riparian zones, only 6 or 7 projects are directly relevant (Table 1). Investigations at the Tifton, Beltsville, and University Park locations dealing with the effects of riparian wetlands in the humid eastern United States on hydrology, water quality, and sedimentation are complimentary. Work at the Oxford location is important because it is unique within the agency. To date, the effort at Durant relevant to this paper is primarily a continuation of a series of studies to measure and document sedimentation rates in natural water bodies. Studies at Reno and other western locations focus on grazing-riparian zone-watershed interactions in the semiarid western United States.

Riparian Zones

Riparian wetland functions differ considerably between the humid east and the semiarid west (Pionke and Lowrance, 1991). In the east, although winter and spring are wetter than summer/fall, rain occurs more or less year-around. Rainfall and runoff which infiltrate in the upper part of a watershed often re-emerge within the riparian zone. The width of riparian zones, which are often wetlands, is governed by topography, climate, and geology. Riparian zones tend to discharge groundwater to their associated streams, sometimes providing 50-95% of the stream flow. Riparian zone discharge or seeps, can migrate seasonally due to climatic fluctuations. Because riparian zone groundwater can be the primary surface water source or can recharge deeper

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Table 1. Overview of Current ARS Research in Wetlands and Riparian Zones

Location	Laboratory	Areas of Study
Tifton, Ga.	Southeast Watershed Research	Riparian zone nutrient budgets, management, erosion and deposition, water budgets, denitrification modeling
Beltsville, Md.	Environmental Chemistry	Riparian zone N budgets, denitrification rates
University Park, Penn.	Northeast Watershed Research	Riparian zone-stream interactions: hydrology and N
Oxford, Miss.	National Sedimentation	Constructed wetland design and operation, riparian zone restoration, riparian zone and wetland sedimentation rates
Durant, Okla.	Water Quality and Watershed Research	Wetland sedimentation rates
Reno, Nev.	Landscape Ecology of Rangelands	Plant communities in a grazed riparian montane meadow

groundwater, riparian processing of nitrogen input from agricultural watersheds is important (Pionke and Lowrance, 1991). Nutrients released from agricultural watersheds can cause water quality degradation and represent a major economic inefficiency (Lowrance et al. 1985b). Riparian wetlands are sinks for nutrients (due to plant uptake and microbial denitrification) and sediments. Published rates of plant uptake of nitrogen range from 22 to 220 kg N $ha^{-1}yr^{-1}$ (Pionke and Lowrance, 1991). Estimated rates of microbial denitrification in riparian zone soils range from 0.0007 to 0.0378 g N $/m^3/hr$ (Gburek et al., 1986) which equates to 60-3,000 kg N $ha^{-1}yr^{-1}$, assuming an average depth of 1 m for riparian zone soil denitrification activity and continuous denitrification year-around. In reality, riparian zone denitrification is likely highly discontinuous, responding to water level fluctuations and nutrient inputs. Three ARS investigations, described in greater detail below, have documented nutrient removal from subsurface waters as they pass through riparian wetlands in eastern watersheds.

Coastal Plain Riparian Zones

Using a system of observation wells, the Southeast Watershed Research Laboratory (SEWRL) has measured inputs and outputs of water and waterborne nutrients for riparian forest ecosystems located in the Little River Watershed (334 km^2) and subwatersheds. Surface soils in this region have high infiltration rates and are underlain by soils of lower permeability at depths of 0.9-1.5 m. Upland area was in agriculture (≈45% and 13% of the watershed was row crop and pasture, respectively) with mixed hardwood forest (30% of the watershed) along the stream channels. Consequently, much of the water movement is in a shallow unconfined aquifer that discharges in the channel or in the riparian zone near the channel (Lowrance et al., 1983, 1984a). Bottomland hardwood forests were effective sinks for N, P, Ca, Mg, and K, but forest management (harvesting mature trees) and minimal disturbance of soil and drainage conditions (to retain denitrification capacity of waterlogged soils) would be required to maintain nutrient removal rates (Lowrance et al., 1983, 1984b and c, 1985a).

Annual denitrification rates were estimated to be about 30 kg N ha^{-1} yr^{-1} (Lowrance et al., 1984c; Hendrickson, 1981). Recent studies indicate that denitrification occurs mostly in the top 10 cm of soil rather than in the saturated zone of the aquifer (Ambus and Lowrance, 1991; Lowrance, In Review). Accumulation of nutrients in aboveground woody biomass is an important long-term sink for N and P. These nutrients can be removed in tree harvest, creating a permanent sink for the nutrients. Large amounts of N, about 50 kg N ha^{-1} yr^{-1}, are stored in the riparian forest of the Little River Watershed (Lowrance et al., 1984c; Fail et al., 1986). Measurement of streamflow nutrient concentrations in 11 watershed units ranging in size from 262 to 11,487 ha indicated that riparian wetlands bordering lower order streams are probably more effective at filtering nutrients than wetlands bordering larger streams, possibly due to the larger fraction of small watersheds occupied by riparian wetlands (Lowrance and Leonard, 1988).

Long-term average erosion rates from cropped lands in the Little River watershed were estimated to be 15,000-20,000 kg ha^{-1} yr^{-1}, but sediment concentrations in streamflow are relatively low. Floods occur as shallow, low-velocity flows across the heavily-vegetated riparian zone, which traps ≈99% of sediments from cropped uplands

(Sheridan et al., 1991). Sediment deposition rates in a riparian forest downslope from a cultivated field in one of the Little River subwatersheds was estimated using Cs-137 activity in core samples (Lowrance et al., 1988). The estimated deposition rate was about 4 times the erosion rate in the adjacent field, evidently due to deposition of sediments from upstream portions of the watershed. Continuing deposition in the riparian zone will result in gradual expansion of the alluvial aquifer and damped hydrologic response (Sheridan et al., 1991). Heede (1991) described similar sediment retention efficiency for vegetated riparian zones in a radically different arid western watershed.

These estimates of riparian zone sedimentation rates compliment Cs-137 measurements by the Water Quality and Watershed Research Laboratory of sediment deposition in the three basins of Reelfoot Lake in northwestern Tennessee and similar work by the National Sedimentation Laboratory (NSL) for a variety of lacustrine, riverine, and wetland sites (McHenry et al., 1975, 1980, 1982, Ritchie et al., 1979, 1983, Dendy et al., 1984). If the observed deposition rates continue, many shallow lakes and riverine wetlands will be eliminated within 50-200 years. NSL work in this area also dealt with trapping of contaminants (e.g., pesticides) in natural freshwater wetlands.

Estuarine Buffer Zones

The Environmental Chemistry Laboratory is conducting studies of mechanisms controlling removal of nitrate from groundwater moving from agricultural areas through non-agricultural ecosystems to a tidal river (Parken et al., 1988). Presumably, better knowledge of nitrate removal mechanisms could lead to enhanced riparian zone management for reducing nutrient loads to surface waters. Field study sites are located adjacent to the Wye River, a tidal river tributary to Chesapeake Bay. Wells have been placed in an established field (soybeans), a grass buffer strip, a forest and a marsh. Nitrate concentrations generally declined in the non-agricultural areas, but were heterogeneous under the forest. The lower nitrate concentrations could have been caused by dilution, plant uptake, microbial immobilization, or denitrification. Denitrification is suspected as the primary removal mechanism because nitrate declines most rapidly during winter while plants are dormant (Comis, 1990). Since removal of riparian zone soil samples for laboratory determination of denitrification activity typically disrupts soil matrix structure and microbial communities, a laboratory microcosm containing 1.24 m^3 subsoil was used to develop an acetylene-blockage method for measuring denitrification rates in-situ (Bragan et al., undated).

The in-situ approach is now being applied to the Wye River field site. Hydrology of the site is quite complex, with hydraulic gradients that vary seasonally due to tidal influence (Parken et al., 1988). Observed groundwater flow patterns were complex, with seepage rates varying by 3 orders of magnitude within 5 m of horizontal displacement (Parkin, personal communication, 1991). Accordingly, dilution effects will be monitored using tracers (Cl^- and Br^-).

Upland Riparian Zones

The Northeastern Watershed Research Laboratory has measured water and nutrient movements in a rugged (240 m relief) ridge and valley watershed (7.4 km^2) in central Pennsylvania. Land use was 57, 35, and 8% cropland, forest, and pasture, respectively (Schnabel et al., 1990). Due to watershed morphology, only 2-4% of the watershed was within the riparian zone. Accordingly, the riparian zone did not play an important role in regulating watershed N export (Gburek et al., 1986). Nevertheless, the near-stream zone (not entirely synonymous with riparian zone) exerted major controls on streamflow chemistry and hydrology (Pionke et al., 1988). Subsurface hydrology was complex with a multi-layer aquifer evidenced by hydrologic and geophysical investigations explaining fluctuations in streamflow nitrate and sulfate concentrations. Streamflow quality varied based on the mix of surface runoff, groundwater inflow, and rainfall present, as quality of each of these sources was quite different. For example, pre-storm (baseflow) stream nitrate concentrations were less than post-storm concentrations because nitrate concentrations were lower for deeper zones in the aquifer. An increasing proportion of streamflow originated from shallow groundwater following storm events (Schnabel, 1986; Schnabel et al., 1990). These findings have been used to develop a conceptual model of near-stream zone hydrology (Pionke et al., 1988).

Riparian Zone Restoration

In conjunction with research dealing with streambank erosion and its control, the NSL

constructed protection works composed of combinations of vegetation and structural materials in 29 treatment areas along 1.5 km of bank located in three reaches of two channels of small, rapidly eroding streams in hilly watersheds in northwest Mississippi (Bowie, 1982). Performance has been monitored for about 10 years; final analysis of results is currently underway. The stabilized sites were initially near-vertical banks of incised channels flanked by agricultural areas, and therefore the vegetative treatments, particularly those involving woody species, constituted partial riparian zone restoration. Research on incised channel erosion has documented channel-riparian zone vegetation interactions (Grissinger and Bowie, 1982).

Additional riparian zone restoration work is planned at three sites in conjunction with a program of research and demonstration of aquatic habitat restoration techniques for unstable, agricultural channels (Shields, Cooper and Knight, In Press). Native black willow (*Salix nigra*) will be used in combination with stone to promote improved habitat for fish and macroinvertebrates at base flow. Rationale for riparian zone restoration designs was based upon extensive data sets documenting water quality and biology of channels with and without riparian zones in hilly northwest Mississippi watersheds. Channels with wide, well vegetated riparian zones experience N peaks during storms about 3 times lower than those without natural riparian zones.

Another riparian zone restoration project is ongoing at the Coastal Plain Experiment Station in Tifton, Ga., by the SEWRL and University of Georgia cooperators. The riparian restoration is being done in conjunction with a Low Input Sustainable Agriculture research project on dairy waste management. A 1.5 ha riparian forest along with a first-order stream channel has been restored with native tree species including yellow poplar (*Liriodendron tulipifera L.*), green ash (*Fraxinus pennsylvanica* var *biflora* (Walt.) Sarg.) and slash pine (*Pinus elliotti* Engelm.). The stream drains an area of about 7 ha which is being used for a study of liquid dairy waste application to forage crops through a center-pivot irrigation system. The area upslope from the restored riparian forest will receive about 600 kg N ha^{-1} yr^{-1} in dairy waste. Movement of N and P in subsurface flow and surface runoff will be monitored as it moves from the upland application area through the restored riparian forest.

Western Montane Riparian Zones

The Landscape Ecology of Rangelands Research Laboratory has investigated plant communities and water and nutrient movements in northern Sierra Nevada montane meadows subjected to cattle grazing. Water table depth was found to control plant community types, aboveground biomass production (Riegel et al., 1990 and 1991a; Svejcar and Trent, 1991), belowground root densities (Manning et al., 1989), and planting success for shrubby willows (*Salix geyeriana* and *s. lemmonii*) (Conroy and Svejcar, 1991; Svejcar et al., 1991). Grazing effects on water table, soil redox potential, and nitrogen (NO_2, NO_3, and NH_4) levels were nil (Riegel et al., 1991b). Apparently the meadow is N-limited and rapidly utilizes animal waste nutrients. Only SO_4 was elevated in grazed treatments over controls.

Manning et al. (1989) found root densities were greatest for wettest areas, and greatly exceeded values reported for other graminoid systems. The apparent importance of water table depth to plant community type and willow planting success suggested that depth lowering due to channel downcutting could impact plant physiology and production. Measurements along a moisture gradient within a meadow indicated that water table depth influenced biomass production but not photosynthesis (Riegel et al., 1990).

Constructed Wetlands

Constructed wetlands have been used to treat municipal wastewater and mine drainage effluent, and hold potential for control of certain non-sediment agricultural nonpoint source pollutants (Cooper, 1989). The NSL is conducting research in cooperation with the Soil Conservation Service using a constructed 4-cell 416 m^2 wetland to treat effluent from a dairy barn ($\approx$100 head). Wetland cells are rectangular basins planted in giant bulrush (*Scirpus validus*) and receive inflow from a 2,100 m^2 primary settling lagoon. BOD, coliform, and nutrient levels are being monitored in influent and effluent. Preliminary results indicated NH_3 removal efficiency by the wetland in the range of 80-90%. NO_3 removal was about 45%.

Expertise

ARS expertise is consistent with the research topics outlined above. ARS teams usually possess

or have access to expertise in acquisition of climatic, hydrologic, and water quality data. Higher levels of expertise center around effects of riparian zones and riparian zone wetlands in relatively small, agricultural watersheds on quality and quantity of shallow subsurface waters. Additional expertise has been developed in the areas of sedimentation rates and nutrient budgets. Research in the areas of wetland construction for nonpoint source control and habitat restoration is in early stages.

Expertise within the agency in the fields of erosion and sedimentation, hydrology, surface and ground water quality, environmental chemistry and ecology is adequate to allow a more extensive program in the area of riparian zone and wetland. However, without additional resources, more work in this area would require redirecting funds and scientists from other investigations.

Data Base

Detailed enumeration of ARS data sets is beyond the scope of this paper. The reader may generally visualize the content of existing data sets from the review of recently completed and ongoing work presented above. However, to recap the above discussion, two primary types of data are available: experimental watershed data and Cs-137-based estimates of sedimentation rates in a wide variety of water bodies. Experimental watershed data sets usually include climatic data and streamflow as a basis. Additional data types vary from watershed to watershed, but include groundwater levels and quality, surface water quality, channel hydraulics, riparian zone vegetation, watershed land use and topography, and riparian zone erosion and deposition rates. Secondary data sets include constructed wetland influent and effluent quality and quantity, and measurements of biological and physical habitat variables from habitat restoration sites.

Accomplishments

Riparian zones in humid eastern watersheds with pre-climax vegetation communities act to lower N and P levels in water moving from agricultural areas to streams. Existing results indicate that both vegetation uptake and denitrification are important nitrate removal processes in riparian ecosystems. It is likely that denitrification is most important when soil temperatures are above freezing but vegetation is largely dormant. Vegetation uptake, especially storage in woody vegetation, is probably most important in the growing season. Results from coastal plain riparian ecosystems show high levels of denitrification in surface soil but low levels in saturated subsoil (Ambus and Lowrance, 1991; Hendrickson, 1981). This finding indicates the importance of maintaining riparian ecosystems where vegetation uptake can remove nitrate at depth and then provide nitrogen inputs to higher organic matter surface soils where denitrification occurs (Ambus and Lowrance, 1991). It is possible that microbial immobilization of N and P, processes which have not been studied in riparian zones, may prove to be important upon further investigation.

Techniques for estimation and in-situ determination of denitrification rates have been developed.

Techniques for estimation of historical sedimentation rates have been developed, refined, and used to show that accelerated deposition threatens to destroy many wetlands that receive drainage from agricultural areas within decades.

The utility of a constructed wetland for treating runoff from a dairy barn has been demonstrated.

Funding Base

Annual funding for the work described above has averaged roughly $500,000 during the period FY87-91. More than half of this amount (roughly $320K/year) is comprised of funding for the laboratory and River Wye site work by the Environmental Chemistry Laboratory. Exact funding levels for some projects are difficult to estimate since they are performed cooperatively with other agencies and are sub-projects within larger work packages. For example, construction phases of the vegetation-structure stream bank stabilization sites and the constructed wetland used for NSL Research were funded by the Corps of Engineers and the Soil Conservation Service, respectively.

Future Direction

Wetland research is currently at an all-time high in the US, with major programs underway within the US Environmental Protection Agency (10 years, $16 million (Sumner, 1991), the Corps of Engineers (4 years, $22 million), and smaller efforts in many other federal and state agencies. Considerable effort should be expended, therefore, to coordinate effort between USDA research

agencies and others. Despite the size of ongoing wetland and riparian zone research programs, additional work will be needed to directly address USDA missions and concerns. Technology is needed to:

1. *Protect and manage existing wetlands that are adjacent to agricultural lands.*

   Many existing wetlands are degraded due to agriculturally-generated sediments, nutrients, and pesticides. Protection and management techniques are needed to use wetlands to provide maximum public benefits consistent with the President's "no net loss of wetlands" initiative (US Soil Conservation Service, 1989). Although it is well established that existing wetlands are effective nutrient sinks and sediment storage zones, management of these areas must be based on a more complete understanding of nutrient cycling and sediment transport processes (Eagleson et al., 1991). Understanding of pesticide dynamics in these systems is at an embryonic stage. Research in these two areas needs to be integrated in order to understand the interactions of management and riparian zone effects on water quality and to provide input to riparian zone models.

2. *Facilitate the use of constructed or restored wetlands and riparian zones to control nonpoint source pollutants, conserve and manage water, and furnish fish and wildlife habitat.*

   Constructed wetland uses extend beyond water quality issues (US Soil Conservation Service, 1989; Karr 1991). Existing environmental legislation mandates biological as well as chemical integrity of receiving waters. Furthermore, research described above indicates that riparian zones and wetlands perform important hydrologic functions. How wide must riparian zones be, and with what types of vegetation, to insure nutrient removal from runoff and shallow groundwater (Pionke and Lowrance, 1991)? What are the most efficient techniques for large scale riparian zone and wetland creation/restoration and management?

   Existing legislation and programs provide unused economic incentives for incorporation of wetland and riparian zone features in farm operations. Wetlands and farmed wetland are now eligible for inclusion in the Conservation Reserve Program (CRP). riparian zones may be enrolled as "filter strips". Current CRP rules allow enrollment of even non-highly erodible cropland if the land is to be planted as a filter strip along a stream, lake or estuary. Filter strips are defined as land areas 33- to 99- feet wide and adjacent to streams or permanent water bodies 5 acres or larger. However, only 40,000 (0.13%) of the 30.6 million acres enrolled nationwide as of the eighth CRP signup were comprised of filter strips (Ribaudo et al., 1990). The CRP provides regional economic benefits (Ribaudo et al., 1990) and can produce per-acre return on investment superior to cash crops (Redmond et al., 1990).

3. *Model and predict the fate of pesticides and other contaminants in wetland and riparian zone. Do contaminant levels build up in constructed wetlands used for nonpoint source control?*

   Much research and development activity is currently directed toward construction of wetlands for water quality control. Wetlands are being used for nonpoint and point sources of municipal and agricultural wastewaters. Short-term results appear promising, but long-term management issues must also be addressed. Maintenance of constructed wetlands may necessitate harvest or removal of plant biomass and organic and inorganic sediments. Economically suitable disposal and management strategies for these materials must be provided. Presumably, knowledge of contaminant fate would also aid in development of practical design criteria for constructed wetland and riparian zone filter strips (US Soil Conservation Service, 1989).

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Status of Wetlands and Riparian Program: Soil Conservation Service

Gene Andreuccetti

Good afternoon. My assignment this afternoon is to provide a status report of SCS wetland/riparian issues. To accomplish this, I will provide a cursory review of current policy which SCS personnel follow in carrying out programmatic mandates. I'd like to cover proposed SCS wetland policy changes. Changes which we find necessary and responsive to 1985-1990 farm bill provisions. I will also touch briefly on wetland expertise, data bases, funding and lastly, accomplishments. The emphasis of this report will be heavy on the 1985 Food Security Act (FSA) and the 1990 Food, Agriculture, Conservation and Trade Act of 1990, as each of these Farm Bills have cast USDA and specifically SCS into a major wetland protection role. A role which at best has created considerable anxiety for our field personnel and which at worst has created controversy and distrust between our agency and our traditional clientele. We needed this workshop seven years ago!

Current Policy - Protection of wetlands

SCS wetland policy applies to technical and financial assistance that will result in new construction, including drainage, dredging, channelizing, filling, diking, impounding and related activity in a wetland.

Any assistance that SCS is called on to provide relative to a wetland requires a documented environmental evaluation before any assistance is provided. The environmental evaluation and wetland criteria used to reach a decision of providing or not providing assistance is driven by Wetland Circular 39, published by U.S. Fish & Wildlife Service in 1956 and reprinted in 1971. With passage of the 1985 Farm Bill, a new definition of wetland was adopted. The new definition was published in 1987 and became policy for our employees as they implemented provisions of the new bill. The key criteria for wetland identification - hydric soils, hydric plants, and hydrology became a national standard to be used by Corps of Engineers, Environmental Protection Agency and U.S. Fish & Wildlife Service as well as SCS.

As you can readily understand, SCS has a minor challenge. We have wetland policy which is driven by circular 39 and another which is driven by Title 12 of the FSA. Obviously we need to make a change and we are. In your packet of handouts, I've included the proposed changes to our wetland policy. Briefly they are:

1. The reference to the term wetland is changed from Circular 39, Wetlands of the United States to the definition of wetland contained in the Food Security Act of 1985 (FSA).
2. The conditions for which the rule does not apply (410.26 b(1)-(6)) has been eliminated.
3. Specific reference to wetland types which may or may not have technical or financial assistance provided has been eliminated.
4. The exemption provided to lands that have been cultivated for at least 3 out of the 5 years before the request for assistance has been eliminated (410.26 d(3)(i)).
5. An additional item was added under the specific policy section of the proposed policy (410.26 d(7)).
6. Under the exceptions section, the term "consistent with the provisions of the FSA Manual" was added to (410.26 e(1)(i)).

The proposed changes would impact all technical and financial programmatic work including the following USDA programs.

a. Swampbuster
b. Conservation Reserve Program
c. Wetland Reserve
d. Water bank
e. Water resource projects in PL-566 - Riverbank
f. National Resource Inventory
g. Soil surveys

The Department of Agriculture has recently announced that, once approved, USDA will adopt new criteria printed in the Federal Manual for identifying and delineating jurisdictional wetlands.

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This criteria will be incorporated into SCS wetland protection policy and procedure.

Expertise

Chief designers of our wetland policy have been our National and Technical Center Biologists, Soil Scientists and Hydrologists. They have received, reviews, and comments from many of you as well as their fellow scientists in Fish & Wildlife Service, Corps of Engineers, and Environmental Protection Agency.

We have tried to maintain professionally trained staffed in all State offices and at some sub-state areas to handle FSA implementation.

Data Base

As we developed and implemented wetland policy, we also have generated data bases either to identify wetlands or to monitor progress and accomplishments as required by statue.

The data base, which is the foundation to all we do in wetlands, continues to be Soil Surveys and more specifically the Hydric Soil list of the United States - the most recent list was published in June of this year. I've included a copy of the front page and overleaf in your handout for your information. I also have a copy of the complete list with me. If someone would like to see it please let me know.

The National Resource Inventory is another data base which provides trends in wetlands and has been useful in formulating National policy.

As we make our county wetland inventories and farm by farm wetland determinations, our SCS/ASCS field staffs are generating a significant photo data base which is the official USDA wetland record. A number of counties have initiated contracts for digitizing this data and you may find it helpful in your work.

Funding

The SCS funding base for most of our wetland activities is in the Conservation Operations line item of the annual budget. SCS is spending on the average of 35-45 million a year on wetland activity and we expect this to continue until all wetlands have been identified.

Accomplishments

SCS has made 1,971,674 wetland determinations. From that number, we've identified 637,710 farms with wetlands, 1,333,964 without wetlands. Some 6,921 have been identified as converted wetlands and 704 were given a minimal effect determination.

The challenges for SCS remain the consolidation of policy and ascertaining the impact of the wetland criteria changes on programmatic workload.

Status of Wetlands and Riparian Program: Forest Service Research

Ann M. Bartuska

While the total acreage involved may be small when the entire land mass is considered, the importance and value of wetlands far exceeds their extent. Wetland ecosystems are critical waterfowl habitat, both for breeding and along fly-ways. Wetland and riparian systems play a major role in flood control and in the improvement of water quality. Additionally, wetland and riparian areas, especially in the western U.S., provide habitat for numerous rare and endangered plants and animals. In the maintenance or enhancement of biological diversity, wetlands and riparian areas are an essential part of the landscape. Economically, recreation and timber production vie as primary users of forested wetlands.

In May, 1991, the Chief of the Forest Service identified Wetlands as a National Problem Area for the FY93 budget; this decision has been carried into the FY94 budget deliberations. Identification of Wetlands as a National Problem reflects the importance of wetland and water issues in the minds of the general public, industry and the legislators. Through workshops with FS scientists and with external cooperators, the program is currently being developed. This report will describe research that has been part of the FS's ongoing efforts. and will identify the key program areas which will be pursued in the future.

Current Program

Forest Service Research is organized geographically into eight Stations. Every Station has a "watershed" project (e.g., Coweeta, H. J. Andrews) which deals with the issues related to water management and site productivity. These studies will not be included in this discussion of Wetlands/Riparian research. Similarly, there are many studies that deal with fisheries habitat or waterfowl habitat; these also will not be included unless they fall within a broader study of wetland ecosystems. Since many wetland and riparian habitats are unique features in a forested or range landscape, every Station has included in their habitat assessments the occurrence of threatened and endangered species (T&ES). These studies will not be singled out in the following narrative. Finally, the types of studies described below, presented by Station, are to give you a flavor of the scope of Forest Service research efforts -- it is not meant to be exhaustive.

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Intermountain Station (ID, MT, NV, UT)

Research on riparian areas has been the emphasis of one of the research units in Boise. ID, whose mission is to develop an improved understanding of riparian and stream habitats. The unit also is concerned with improving methods for habitat management, for conservation of resources, and for production of livestock, wildlife and fish. Research has consistently examined the role of riparian habitats on the landscape as islands of diversity, including the abiotic characteristics of these habitats. For example, studies have determined that 59 percent of small land birds in western Montana use riparian habitats during the breeding season, while 53 percent of Idaho's neotropical migrant land birds use these areas for breeding habitat.

The same features of riparian areas that attract "wild" species, also make these systems desirable to livestock. Research has described the degradation of many systems due to overuse and has made significant progress in rehabilitating damaged ecosystems. Fundamental research on plant community succession following restoration is ongoing as are basic phenological studies of important riparian species.

North Central Station (IL, IN, IA, MI, MN, MO, WI)

The region is a complex ecosystem of lakes, wetlands and streams where recreation shares land use with timber production. The Station has been studying the peatland ecosystem since the 1950's, with much of the work done on the Marcell

Experimental Forest. Research has emphasized the understanding of hydrology and biogeochemistry. Recently that has meant a thorough analysis of the impact of acidic deposition on peatland chemistry. Efforts are continuing to examine methane production and CO_2 flux from northern peatland ecosystems.

In addition to fundamental studies on wetland processes, Station researchers are also examining the cumulative effects of alternative management systems. This research is coordinated with the forest engineering project, which is developing harvesting techniques and technology for use on unstable soils.

Pacific Northwest Station (AK, OR, WA)

Alaska has many unique ecosystems including 40 million acres of forested wetlands. Much of the research has emphasized the forested landscape of the southeastern panhandle, including some characterization of associated wet-muskegs and riparian areas. The most significant opportunity for wetlands research lies within the Copper River Delta. The CRD stretches 75 km along the south central coastline of the Gulf of Alaska and is rich in waterfowl and fish habitat. The dynamic nature and diversity of the ecosystem will serve as the basis for planned fundamental research on the structure and functions of complex delta systems.

In Oregon and Washington, research has concentrated on riparian habitat restoration and management in association with other management activities.

Rocky Mountain Station (AZ, CO, KS, NE, NM, ND, SD, TX, WY)

Scientists in Tempe, AZ have led the research effort to understand the functioning of riparian areas in the southwestern U.S. Initial focus was on animal (domestic and wild) interactions in these systems.

Generally, research has emphasized the management of riparian areas to enhance, maintain, or restore riparian vegetation and hydrologic conditions in these ecosystems. Research has resulted in management guidelines for use in the field as well as basic information on flora and fauna species composition and distribution. Ongoing studies deal with the structure, function, and composition of these ecosystems and the interface with the aquatic system (fish and water). Studies are being done on channel dynamics and on water table controls on riparian vegetation. The impact of livestock grazing on riparian areas is a major emphasis area throughout the Rocky Mountain West, as evidenced by similar research in the Intermountain Station.

Southeastern Station (FL, GA, NC, SC, VA)

There has been a long history of research in wetland systems, focusing primarily on stand productivity in pocosins (Croatan NF) and bottomlands (Frances Marion NF/ Santee Experimental Forest). To provide greater focus, the Center for Forested Wetlands was established in 1988, in association with Clemson University, at the Forestry Sciences Laboratory in Charleston, SC. Emphasis has been on growth and productivity of wetland tree species under different management activities with special attention being given to studies of soil chemistry and the role of flooding on plant physiology. Hurricane Hugo has provided a new opportunity to evaluate effects of catastrophic disturbance on the hydrology and biogeochemistry of forested systems, including wetlands. Efforts are increasing in the area of wetland restoration, both at the Santee and at the Savannah River Forest site.

The Station has recently initiated research to examine the use of buffer strips to protect forested wetlands from impacts due to upland silvicultural operations. This is an extension of the IMPAC (Intensive Management Practices) Unit's studies on nutrient and herbicide transport in subsurface systems.

Southern Station (AL, AR, LA, MS, OK, TN, TX, PR)

Bottomland hardwood forestry research began at Stoneville, MS in 1937 and, while the specific problems have changed, the basic mission of the laboratory to study regeneration and management of southern hardwoods is current. Locations of concern include the Mississippi River Delta with associated swamplands and other major and minor river drainages in the central-South. Emphasis is increasing on natural regeneration methods for even and uneven-aged forests. Scientists are studying growth and yield, insect and disease problems, as well as examining the role of these wetland systems at all stages of growth as wildlife habitat. Factors include habitat age or successional sere, size of area, species composition, structure, landscape context, and hydrology.

Other areas of research are engineering and

economics. Just as in the North Central Station, the management of bottomland sites has necessitated the evaluation of harvesting methods, leading to systems for reducing site impacts on wetland forests. The Economics Unit in New Orleans continuously monitors and analyzes federal and state wetland regulatory laws as they relate to forest management and forestry practices. Research has also been done on the economics of converting forested wetlands to crop production in the Lower Mississippi Alluvial Plain.

Both Southeastern and Southern Stations are explicitly identifying wetland systems in their Forest Inventory and Analysis (FIA) data base. Southeastern Station has taken a look at additional variables which could be used to better characterize forested wetlands.

Future Program Direction

The proposed program to be initiated in FY93 is comprised of five broad categories of research. Geographically, the areas of greatest interest are: southern bottomland hardwoods and southeastern coastal wetlands; peatlands in the north central region; and, riparian habitats in the west. In addition, the Copper River Delta of Alaska has been identified as a unique wetland resource. The proposed research program will emphasize these areas, but will include other areas identified as high priority by specific research Stations.

The following elements were identified by a team of Forest Service scientists and managers in a workshop which took place August 20-21, 1991, in Washington, D.C. The proposed research direction will undergo further review by all Research Stations so it should be viewed as a preliminary "strawman" to stimulate discussion.

Ecosystem Dynamics

1. Develop ecosystem models to predict stand and community compositional changes, integrated with ecophysiological processes.
2. Understand the hydrologic regime of wetland systems, including patterns of temporal heterogeneity (i.e., timing and duration).
3. Identify the interrelationships of water quality and quantity on wetland "health".
4. Understand natural patterns of disturbance as part of the baseline characterization.
5. Influence of herbivory on structure and function of wetland ecosystems.
6. Evaluate habitat in relation to faunal communities; what are the requirements for maintaining a viable population?

Restoration and Rehabilitation

1. Restore totally degraded or lost wetland systems through hydrologic manipulation and revegetation.
2. Restore the productive capacity of wetland forests by "improving" the species complement.
3. Evaluate the regenerative capabilities of a degraded system.
4. Identify the "keystone" species that can influence the success or failure of restoration or creation.
5. Develop regeneration methods for preferred wetland species.
6. Evaluate the success of mitigation and restoration on diverse sites.

Management of the Wetland Resource

1. Evaluate the influence of livestock grazing and domestic foraging on patterns of vertebrate abundance in riparian wetlands.
2. Determine effects of alternative management practices on wetland ecosystems.
3. Identify techniques for management of habitats to maintain biological diversity.
4. Establish guidelines for management decisions to control insect or disease impacts on wetland community structure.
5. Develop low impact harvesting and transportation methods for use in wetland ecosystems.
6. Develop the information necessary for Best Management Practices in land management operations and evaluate their implementation.
7. Evaluate the impact of developmental pressures, including urbanization on wetland functions.
8. Describe recreation impacts on wetland values or functions, including wilderness areas.
9. Determine the fate of pesticides and herbicides in wetlands, either when used in the wetland system or in the surrounding landscape.

Socioeconomic Values of Wetlands

1. Valuation of the different functions or components of wetlands.
2. Determine impacts of changing wetland regulations on timber supply.
3. Determine cost-benefit and distribution of wetlands protection and management.
4. Evaluate the cost of implementing Best Management Practices (BMP's).
5. Analyze legislation or regulations for impacts on land management decisions.

Landscape-Scale Linkages

1. Identify effects of land use patterns on wetland occurrence and functions.
2. Determine the influence of landscape characteristics on the suitability of wetlands for wildlife.
3. Determine the influence of landscape characteristics on hydrology and water quality.
4. Evaluate the contribution of wetlands to the biologic diversity across the landscape.
5. Determine the role of wetlands as interface between upland and water systems.

Status of Wetlands and Riparian Program: National Forest Service System

Larry Schmidt

Introduction

The Nation's riparian and wetlands provide productive fisheries and wildlife habitat, diversity of aesthetic scenery and recreation sites, sediment filtering and flood reduction, water of high quality for downstream users, points of recharge for ground water, commercial timber, and sustainable forage for domestic livestock and wildlife. These beneficial uses and values depend on healthy riparian areas. Riparian conditions also provide a good indication of the overall health of the surrounding watershed and its resources. Improving the productivity of these highly valuable riparian areas requires implementing wise and consistent resource management based on current and future technologies and research findings.

The banks of our Nation's water courses, lakes and wetlands, known as riparian areas, are receiving increasing attention. Riparian areas are multi-faceted water adjacent ecosystems. They possess both wetland and upland attributes. Riparian areas are commonly found along streams, rivers, springs, lakes, and wetlands. They reflect the integration in both time and space of interactions occurring among geomorphic processes and landforms, terrestrial vegetation, and aquatic communities. They are the part of the landscape that provide the vital transition between forest and stream, hillslope and valley, and terrestrial and aquatic ecosystems. They also serve as the focal point for the transport of watershed constituents, including water, sediment, nutrients, and toxic materials. These landscapes provide an ideal location for interdisciplinary research. Some important riparian discoveries have been made but knowledge needed for wise management and timely improvement requires new and expanded research and development emphasis.

The Forest Service is responsible for managing 198 million acres of public lands throughout the United States. Valuable wetlands and riparian areas comprise approximately 6 percent of the National Forest. The small areal extent belies their importance in providing favorable water flow and quality conditions.

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Policy

The Forest Service policies on wetlands and riparian areas were initially established in 1978. The National Forest Management Act of 1976 required, in part, that soil, slope and other watershed conditions not be irreversibly damaged and that protection be provided for streams, streambanks, shorelines, lakes, wetlands and other bodies of water against detrimental changes in water temperature, blockages of water courses, and deposits of sediment where timber harvest activities are likely to seriously and adversely affect water conditions or fish habitat. A riparian policy was developed to wisely manage the areas adjacent to bodies of water. Riparian ecosystems were defined as those areas of land adjacent to perennial bodies of water identified by vegetation communities that require free or unbound water during the growing season to grow and reproduce. Thus, riparian ecosystems include areas in addition to wetlands that have vegetation with roots that tap the capillary zone that lies above the saturated zone typically associated with wetlands.

The wetland policy is based on the requirements of Executive Order 11990 of 1977 governing wetlands. It is treated together with the requirements of Executive Order 11988 regarding floodplains. In general the policy provides that Federal Agencies will avoid to the extent feasible adverse impacts associated with the occupancy and use of wetlands.

Specific policies

- Manage riparian areas in accord with all applicable laws.
- Follow the principles of multiple use and sustained yield. Protect and improve riparian area resources.
- Give preferential consideration to riparian area dependent resources when conflicts among land uses activities occur.
- Identify, map and evaluate riparian areas prior to implementing projects. Recognize wetlands as specific management areas.

- Give special attention to lands along streams capable of supporting riparian vegetation including at least an area of 100 feet from the edge of perennial streams, lakes, and other bodies of water.
- Avoid adverse impacts associated with occupancy, modification, destruction, or degradation of wetlands where practicable alternatives exist.
- Preserve and enhance the natural and beneficial values of wetlands.

Existing Program

The riparian and wetland management issues are identified in The Forest Service Program for Forest and Rangeland Resources: A long-Term Strategic plan that describes the recommended 1990 RPA Program. Each National Forest Land and Resource Management Plan addresses the riparian and wetland issues for the particular forest. Wetland and riparian areas are identified and management standards and guidelines are established to meet the policies, goals, and objectives of the particular plan.

The Chief of the Forest Service has given special emphasis to managing riparian areas through a National Strategy. The strategy establishes the goal of improving conditions to meet forest plan standards on 75 percent of the riparian areas that are currently in unsatisfactory condition by the year 2000, and the remainder by 2010. To accelerate this effort the Chief has proposed a specific riparian budget initiative for FY 1993.

Agency Expertise

The Forest Service relies on a cadre of scientifically trained specialists in a variety of disciplines including water, soil, air, ecology, geology, fisheries, wildlife, forestry, range, recreation, minerals, and engineering. These specialists operate in interdisciplinary teams to evaluate conditions and design an integrated management strategy to achieve the goals of forest plans. These specialists are involved in all phases of project development and implementation. In addition, expertise from forest research and other agencies are often consulted. The Forest Service also provides consultation and advise to State Foresters through our State and Private Forestry Program.

Data Bases

Work is underway in each Region of the Forest Service to identify the extent and condition of riparian and wetland resources. However, a national data base for riparian and wetlands does not exist. The advent of geographic information systems will likely result in a common data management methodology. Work is currently underway to develop criteria for integrated resource inventories.

Funding Base

Funding for riparian and wetlands are not specifically tracked in the current budget process. However, substantial emphasis is being given to riparian and wetland management by projects in watershed, range, wildlife & fisheries and other areas. We have identified that $17.4 million annually will be required to meet the objectives for improving rangeland riparian areas in the eleven Western states.

Accomplishments

The National Forests have:

1. Established goals, standards and guidelines for management of riparian areas and wetlands in forest plans.
2. Demonstrated through projects that substantial improvements can be achieved with improved management.
3. Adopted National and Regional Strategies and developed action plans for improving riparian areas and wetlands.
4. Agreed to participate in the North American Waterfowl Plan.
5. Developed numerous partnership projects with private sector companies and interest groups to improve riparian and wetland habitats.
6. Developed and applied techniques for restoring wetland values through road maintenance activities in the Southwest.
7. Provided training in stream system morphology and restoration techniques that use the natural processes as a basis for sustainable improvement.
8. Developed and applied a variety of site specific conservation measures to protect and improve riparian areas and wetlands.

Key Water Resource Topics

1. Improved understanding of the processes and thresholds associated with deterioration of riparian areas, watersheds and wetlands is

needed in order to establish appropriate use strategies and identify appropriate limit of acceptable change.

Situation

One of the most critical needs is to develop methods to evaluate and mitigate the direct and cumulative effects of land management activities within a watershed. This knowledge is especially important where there are opportunities to avoid many potential problems through design and incorporation of state-of-the-art practices in new operations. Knowledge of processes and thresholds is also important to correct past problems and define limits of acceptable change that will avoid cumulative damage to watershed, wetlands and riparian ecosystems. Human activities can cause rapid changes in flow characteristics that result in channel and vegetative deterioration; for example, changing subsurface flow to surface flow or changing diffuse flow to concentrated flow.

Questions

- How do specific watershed activities and rehabilitation treatments effect the dominant geomorphic and biologic processes operating in riparian areas, wetlands and their surrounding watersheds?
- How can we evaluate the effects in advance of both natural and man-caused disturbances (including effects of diversions, impoundments and changing global climate) on riparian and wetland ecosystems and adjacent slopes?
- What riparian, wetland and watershed plant community complexes indicate watershed sensitivity and what is the role of riparian vegetation in maintaining channel and floodplain stability?
- What variables can be used to set limits of acceptable change, track proper management and indicate appropriate conditions to support threatened or endangered species?

2. We need to know the cumulative capacity of riparian and wetland ecosystems to intercept and/or absorb toxins, sediments, and nutrients from surface and groundwater transport as a result of silvicultural, grazing, recreational, agricultural, and development activities both in the riparian area and the surrounding watershed.

Situation

In the future, it will be necessary to develop methods for evaluating and mitigating the direct and cumulative effects of land management, notably forestry, grazing, agriculture, and urbanization on the structure and health of riparian and wetland ecosystems. One aspect of mitigation is understanding the role of forested wetlands and vegetation buffers along rivers and streams in protecting and enhancing the variety of resource values and functions. For example, what is the assimilative capacity of various riparian ecosystem buffers and what are the features that control the capacity for various constituents.

Questions

- How effectively can riparian vegetation serve as a last line of defense against the water quality impacts of land use occurring on upstream watersheds?
- What is the composition, width, and effectiveness of riparian vegetation buffers and filter strips required along water courses for removing N, P, toxic material, and sediment when addressing non-point source (NPS) problems?
- To what extent are vegetation buffers a viable tool for mitigating the impacts of urbanization, population growth, and agriculture?
- What special management is required to maintain viable riparian ecosystems in the face of windthrow and other disturbances?

3. In some cases adequate technology may be available to more effectively manage wetland and riparian areas, yet there is a gap between what is known and what is applied.

We need a means to identify and close these knowledge gaps. For example, information gaps currently exist in both our understanding of the important processes operating in the riparian area and as a result satisfactory predictive models for comparing alternative management scenarios are not available. Because of the absence of predictive models, land managers have adopted numerous and inconsistent strategies for evaluating and mitigating cumulative effects of land management on the riparian and wetland resource. These strategies generally include some combination of scheduling, dispersion, and zoning. However, we are unable to predict interactions among multiple processes over larger areas and longer periods of

time, including the dynamics of sediment transport in high gradient streams; input, transport, and role of coarse woody debris in streams; relationship between valley floor geomorphology and fish populations; movement of water and nutrients through floodplains; and the relationship between streamside vegetation and aquatic community structure.

Questions

- How can we identify sensitive and critical riparian areas and components of the surrounding watershed? In this context, sensitive refers to those areas that are prone to physical or biological change while critical areas are those where changes are likely to be significant to a resource or value.
- What are the sensitive features that a model must address to effectively guide management?
- What are the precursors of change that can be modeled and monitored to anticipate future change?
- Can existing water routing models be extended to accommodate the effect of different land uses on stream flow and sediment regimes?
- What are the range of acceptable seral states for riparian areas and wetlands and what are the agents of change relative to use activities, ecological factors and channel or geomorphic regime?
- Consistent and timely means of providing essential riparian information needed to guide wise decision making and to provide a basis for focusing and extrapolating research results is lacking.

Situation

A substantial amount of administrative effort is being devoted to developing regionally-based classification schemes and inventory riparian areas. Most of these approaches are focused on responding to the perceived needs of a specific resource function. An integrated information acquisition approach may provide more timely and useable data in a less costly way.

The extraordinary amount of time focused on classification and inventory has reduced our ability to provide urgently needed actions on-the-ground. Much of the data demanded by the various approaches may have little utlilty in guiding management or scientific decisions. More evaluation of both actual need and sensitivity is needed.

Questions

- What are the questions that could be answered by an inventory or classification?
- What key measurable attributes indicate health, trends, and risk of change in riparian areas?
- What is the current level of information provided by existing inventories?
- What opportunities exist to expedite an inventory using remote sensing, statistical samplings, and geographic information systems?

4. Accelerated rehabilitaion of extensive past damage to channels and riparian systems of riparian areas, wetlands and their surrounding watershed is needed.

Situation

Most areas of the country have experienced past damages to watersheds and riparian areas. These damages occurred because the knowledge needed to assure wise use was unavailable. Many of the most severely disturbed areas still need some rehabilitation to regain their functional value. For example, riparian areas throughout the Inland West occupy less than 3 percent of the total area. These areas have deteriorated to the extent that as much as 90 percent of riparian areas have been altered or lost as a result of unwise land use that occurred during the past 100-150 years. These losses have occurred because of vegetation modification (logging, phreatophyte control, etc.) cultivation, irrigation development, fencing, grazing, and development of public access and use without knowledge of measures to limit impacts.

Questions

- Are there strategic rehabilitation actions that can take advantage of geomorphic processes and flow energies to make riparian areas more stable?
- Would a strategic treatment approach reduce initial and maintenance costs?
- What role do sideslope and streamside vegetation have in regulating channel processes, such as peak flow generation and sediment transport?

Undisturbed riparian and wetland ecosoystems have a high capacity for dissipating streamflow energy. How much of this energy dissipation capability is needed to limit change, what pathways does energy take, and what are the alternative ways of restoring and acceptable level of energy sinks in the system?

How do incised channel systems evolve and what is the appropriate role of rest, revegetation and channel structures in riparian rehabilitation?

What specific sequences of treatments are needed for establishing an acceptable long-term balance between watershed condition and riparian health as related to different management objectives?

Our ability to evaluate the economic and social values associated with healthy riparian areas, wetlands and watersheds as contrasted with deteriorated contitions needs substantial improvement.

Situation

The economic value of healthy wetland and riparian areas as contrasted with deteriorated ones has received scant attention. More knowledge of the possible improvements and their value might encourage investment by the private sector. Little is known about the rate and amount of possible improvement in riparian areas, wetlands and watersheds and the market and non-market values associated with improving their condition at the landscape scale. A diverse group of ecological and economic values is changed by improvements. For example, we know that some treatments can change an ephemeral arroyo to a constantly flowing stream. Also, floodplains with luxuriant vegetation growth reduce flood peaks. Yet, we have little knowledge of the values and tradeoffs associated with these and similar changes. Knowledge of the values would encourage and support investments to improve conditions.

Questions

Which wetland and riparian areas have the greatest potential for increased vegetative productivity and species diversity responses?

- In which areas will plant community occur quickly, and what pathways will these changes take?
- Which riparian areas have the greatest potential for increased forage and habitat values, and how can the preferred timing and intensity of grazing be defined in economic terms?
- To what extent will habitat for wildlife and fish improve upon wetland/riparian/watershed restoration and what will be the resulting market and non-market values?

What is the rate and amount of water exchanged between surface and groundwater sources and how does it affect associated wetland and riparian processes (e.g., streambank and alluvial fan recharge, ground water recharge, sustained flow, reduced flood flow, etc.)?

Future Trends

Watersheds, riparian areas, and wetlands are potentially vulnerable to changes resulting from current and emerging concerns including global climate change, atmospheric deposition, and water quality decline. The major changes that must be anticipated and managed are associated with urbanization, agriculture uses, livestock and wildlife grazing, recreational use, timber harvest, and similar activities. The research challenges are significant and complex. Potential breakthroughs in our knowledge are vital to the health of wetlands and riparian areas and the public that depends on their multiple values.

Many times apparently subtle changes in flow or landscape conditions results in dramatic changes to riparian areas. Better management of riparian areas requires an improved understanding of geomorphic processes and the influence of hydrological changes in the tributary watershed. This understanding is vital to the design and incorporation of soil and water conservation measures that will prevent the types of impacts that have occurred in the past. Prevention of impacts is far less costly than attempting to repair damages after they occur.

Meeting watershed, wetland, and riparian management will require building the neccessary means to accomplish forest and rangeland activities without adverse effects and to accelerate restoration of deteriorated areas as part of ongoing activities.

Note: This paper includes a substantial portion of the content of WILDLAND RIPARIAN AREAS - THESE VITAL AREAS NEED EXPANDED RESEARCH EMPHASIS, a paper by a panel including: Leonard DeBano, Gordon Grant, Gerald Stokes, Larry Schmidt, presented at the Forest Environment Workshop in Ft. Bragg, California, March, 1990.

Additional input was provided by: Russ LaFayette, Max Copenhagen, Ken Roby.

Facilitated Workshop Session: Wetland and Riparian

The participants of the workshop were divided into four working groups, one group for each of the four issues, with representation from each of the agencies. The overall charge to this working group was to explore the possibilities for developing interagency cooperation within the Wetland and Riparian issues. More specifically the working group was to:

1. Determine important **topic areas** that are common to all four agencies, prioritize the topics and develop a rationale explaining why the top 3 to 5 topics are important.

2. Develop a **vision** for the future direction of water resource programs, including identification of research and technology transfer needs and organizational needs and a brief vision statement.

3. Identify and prioritize any major **barriers** to strengthening interagency cooperation.

4. Develop a list of **recommendations** to implement the vision statement and strengthen interagency cooperation.

Each work group was assigned a trained facilitator to assist the group in reaching a consensus and a recorder to document the working groups process and outputs. The outputs of each working group were typed at the end of the day and made available to the working groups the next day and to all participants at the end of the workshop during the wrap-up discussion session. We wish to thank the facilitator's and recorders for outstanding efforts during the workshop.

Lead Facilitator: **Dave Miller**, Forest Service Information Systems, Washington D.C.

Wetland/Riparian Facilitator: **Andrea Martinez**, Forest Service, Silver City, NM.

Recorder: **Scott Knight**, Agricultural Research Service, Oxford, MS.

Cross Cutting Topics Identified

I Effects of various management strategies on the processes, functions, and values of riparian/wetland ecosystems.

II Restoration and rehabilitation of wetland/riparian zones. Develop technologies and methods for wetlands/riparian zone restoration and rehabilitation. Restoration and rehabilitation encompasses restoration of wetland/riparian zone productive capacity and/or function, e.g., timber production, nutrient removal from non-point sources, sediment control, fish and wildlife habitat, hydrologic function. Determine methods for evaluating success of wetland/riparian zone restoration and rehabilitation.

III Evaluate the importance and linkage of wetland/riparian ecosystems to the landscape and to downstream receiving waters such as lakes, estuaries, and coastal zones.

IV Understand fundamental biological, chemical, and physical processes underlying wetland/riparian zone functioning and use of this knowledge to improve inventories across time and space.

V Improve the transfer of research findings to managers and practitioners. Improved guidelines and procedures (packaging of findings and models) for management applications (may be more than one

audience or user). Involvement of both managers and researchers in a) research design; b) model development; c) study sites; and, d) documentation/publication.

VI Develop principles for the planning, design, and operation of constructed wetlands for the management of agricultural non-point source contaminants from agricultural lands, livestock operations, and farmsteads in the context of comprehensive resource management systems.

VII Analyze the range of relative values (including social, ecological, and economic) associated with riparian zones/wetland functions.

VIII Analyze the effects of the legal/political/institutional framework on riparian zones/wetland management options, and the opportunities for institutional change.

Cross Cutting Topic I

Effects of various management strategies on the processes, functions, and values of riparian/wetland ecosystems.

Rationale:

This topic is important in context of current and potential lawsuits against management agencies. There is a need to offer economic returns to both private and public managers to increase acceptance. This item will insure that value functions will be protected. This topic will ameliorate non-point source pollution.

Current Situation:

- Inadequate understanding of people's needs and values at which management is directed. What is important to people?
- Various management strategies have been done, but no evaluated in terms of meeting societies' needs.
- Scientific evaluation of management is never good for some approaches, absent for others.
- Inadequate knowledge to scale up from site specific management actions to multiple sites or regions.
- Analysis of current situations is incomplete and existing information on current condition is inadequate or uneven, e.g., value of large woody debris for fish.
- More information is available on riparian management than other wetland systems, e.g., bottomland hardwood, wetlands.

Vision Statement:

USDA agencies will work cooperatively to address societal needs by providing information for manager's to make successful decisions regarding riparian/wetland ecosystems.

Research Needs and Technology Transfer Needs:

- Fundamental understanding of functions in time and space.
- Analyze range of values (socio-economic, non-commodity) of concern and the legal framework to address.
- Effectiveness of management strategies to meet goals, i.e., water quality, fisheries, biological diversity. Consider models at system and decision support levels.

Organizational Needs:

- Address increased staffing in critical areas, e.g., hydrologists in Forest Service Research; ecologists in ARS.
- Agency commitment to inventory and monitoring in research and management.
- Pursue "all land" inventory to complement SCS farm-by-farm wetland inventory. Could be built into FIA of FS.
- Agencies' commitment at all administrative levels, to interdisciplinary, issue-oriented teams.
- Decision models for land managers which interactively incorporates research results.

Cross Cutting Topic II

Restoration and rehabilitation of wetland/riparian zones. Develop technologies and methods for wetlands/riparian zone restoration and rehabilitation. Restoration and rehabilitation encompasses restoration of wetland/riparian zone productive capacity and/or function, e.g., timber production, nutrient removal from non-point sources, sediment control, fish and wildlife habitat, hydrologic function. Determine methods for evaluating success of wetland/riparian zone restoration and rehabilitation.

Rationale:

This topic is needed in order to meet the goals of the Clean Water Act. This item will also establish the capability of the land and re-establish/restore the non-commodity value of the land. It will also help meet public expectations.

Current Situation:

- Relatively low level of funds directly targeted to this topic. (See agency status reports)
- Agencies have not responded to past damage to channel and riparian systems and their surrounding watersheds. Chemical goals of Clean Water Act have been emphasized more than biological goals. For example, despite the frequency of physical habitat as a limiting factor, billions have been spent on wastewater but only a few thousands or millions on aquatic habitat restoration.
- Livestock grazing impact on riparian zones is a politically hot issue.
- Due to technical and resource limitations, agencies have not responded adequately to past damages to riparian and wetland zones.
- Previous efforts have been largely piecemeal and have focused on treatments rather than results.
- Riparian and wetland zones offer huge potential for control of non-point source pollutants and yield of commodity and non-commodity benefits to landowners and public.
- Channel incision has impaired riparian and wetland zone areas throughout large geographic regions.

Vision Statement:

Riparian/wetland owners and land managers identify and understand essential functions and values to be obtained by restoration activities applied to deteriorated areas.

They are able and motivated to develop and apply an improvement strategy that:

- Sets appropriate priorities for action
- Acts in concert with natural processes/functions
- Makes appropriate adjustments in use patterns
- Applies measures strategically to attain objectives
- Achieves timely results
- Optimize economic/social return

Research and Technology Transfer Needs:

- Determine restoration/rehabilitation methods that are based on hydrologic manipulation and/or revegetation.
- Identify "keystone" plant species that exert major influence on success or failure of restoration/rehabilitation.
- Examine effects of riparian forests and woody debris on hydrograph (floods, lowflows, etc.).
- Generate design criteria for restoring riparian vegetation in areas subjected to livestock grazing.
- Quantify economics of establishing and managing wetland and riparian zones.
- Determine width, composition, and effectiveness of restored riparian zones for removing nitrogen, phosphorus, and contaminants from NPS from surface and subsurface flows.
- Develop knowledge that allows development of restoration prescriptions and designs that take advantage of geomorphic processes and flow energies.
- Develop methods for rehabilitating riparian zones, wetland zones, and associated habitats impaired by channel incision.

Organizational Needs:

- SCS should fully utilize provisions of '85 and '90 Farm Bills that encourage wise use

and restoration of riparian and wetland zones.

- o Heighten collaboration among USDA agencies with respect to wetland/riparian research.

- o Develop coherent USDA wide policy and terminology for wetlands and riparian zones (all agencies).

- o Improve interaction between research (ARS, Forest Service Research) and action (SCS, Forest Service) agencies to: 1) identify knowledge gaps and research needs; and, 2) improve technology transfer.

Cross Cutting Topic III

Evaluate the importance and linkage of wetland/riparian ecosystems to the landscape and to downstream receiving waters such as lakes, estuaries, and coastal zones.

Rationale:

One cannot deal with other items except within context of this topic. Management of single variables will not work. This item is essential to cumulative effects analysis. It helps meet public expectations for ecosystem management.

Current Situation:

- o Watershed models are available but lack adequate processes that represent on wetland/riparian ecosystems.

- o Action agencies have limited data available to form interim management recommendations.

- o Current management does not account for landscape linkages and effects on downstream receiving waters.

Vision Statement:

The linkages of wetland/riparian ecosystems to other land users in a watershed or landscape help determine both the stresses placed on the wetland/riparian zones and the functional roles of these ecosystems. Quantitative analysis of these linkages will lead to an improvement of our understanding of the effects of landscapes on wetland/riparian ecosystems and will provide important information on the special roles such as chemical sinks, habitat, flood water retention, etc., performed by wetland/riparian ecosystems. These special roles largely determine the effects of management and intensive land uses on critical and fragile ecosystems such as estuaries. This new knowledge will lead to better conceptual and simulation models of the dynamics of complex watersheds and landscapes and the effects of management on wetlands and coastal zones. These models are needed for wise management of complex systems subject to competing societal demands.

Research Needs:

- o Identify influence of landscape/land use(s) patterns on wetland/riparian structure and function (including animal usage).

- o Evaluate/quantify contributions of wetland/riparian ecosystems to biological diversity.

- o Quantify the extent and distribution of wetland/riparian ecosystems necessary to support beneficial uses of water resources.

- o Evaluate the effectiveness and potential effectiveness of wetland/riparian ecosystems in ameliorating the effects of non-point source pollution in river basins, estuaries, and coastal zones.

- o Develop applied landscape models which integrate wetland/riparian system processes.

Organizational Needs:

- o Liaisons/scientific exchanges among USDA/non-USDA agencies including research/management and research/action agencies.

- o Development of USDA working groups on wetland/riparian zones with non-USDA observers.

- o Development of regional research/ technology development projects around specific regional projects.

- o Establish regular USDA workshops to facilitate cooperation and evaluate progress.

- o Establish mechanisms for exchange between research/technology community and policy makers, regulators, and legislators.

General Barriers and Recommendations

Barrier I:

Our traditional mission, that is how we have done business and who we do business with, limits our ability to cooperate in wetland/riparian issues.

Recommendations:

Form upper agency coordinate group within the Department to develop internal policies. Secretary could then issue direction that:

- o Joint efforts in wetland/riparian management and research a high agency priority.

- o Focus resources necessary to see that policies are implemented.

Barrier II:

Lack of understanding and inadequate communication in terms of their goals between researchers and managers and technology transfer specialist.

Recommendations:

- o Develop interdisciplinary teams which include both managers and researchers to identify and address local, regional, and national issues,

- o Increase the use of liaison positions to facilitate technology transfer between research and management,

- o Utilize demonstration areas (watersheds, forests, farms, etc.) to implement practices, evaluate effectiveness and transfer information,

- o Increase utilization of trouble shooting, multi-agency, interdisciplinary teams to assist land managers in applying available technology (example SWAT teams),

- o Increase participation of researchers in technology, management activity and program reviews,

- o Schedule second interagency conference in Water Resources before December, 1994.

Barrier III:

Inadequate incentives for USDA agencies to increase effectiveness of technology transfer.

Recommendations:

- o Examine and implement changes to reward systems that increase researcher incentives to engage in information transfer activities.

- o Develop incentives for managers to participate in development and application of pertinent research.

Barrier IV:

Inadequate knowledge base, skills and expertise to deal with complex systems.

Recommendations:

- o Fund additional research and technology transfer in wetland/riparian processes, models, restoration and economic and social incentives for stewardship.

- o Increase involvement of social scientists in wetland/ riparian ecosystem research in a landscape context.

- o Accelerate USDA efforts to determine the public's needs and desires in order to direct conservation incentives programs, wetland and riparian research efforts, and agency training.

- o Integrate policy and economic goals with physical, chemical, and biological understanding of wetland/riparian ecosystems.

- o Establish an interagency Wetlands Research and Technology Institute.

Barrier V:

Conflicts exist with other USDA agencies as well as non-USDA agencies in management related to wetland/riparian ecosystems.

Recommendation:

Establish national USDA committees to govern and coordinate policies, regulations, and research related to wetland/riparian ecosystems.

Barrier VI:

Regulations developed without input from researchers can inhibit the use of innovative technologies in wetland/riparian ecosystems.

Recommendation:

Establish national and regional inter-departmental coordinating committees to resolve conflicts related to policies and management for wetland/riparian ecosystems.

WATER QUANTITY AND WATER QUALITY

Issue Session

Status of Water Quantity and Quality Program: Forest Service Research

Edward S. Corbett

The Forest Service has been involved in studies of water since the early 1900's starting with the Wagon Wheel Gap watershed experiment in Colorado. Hydrologic research has generally been viewed in the context of experimental forests and watersheds, hydrologic laboratories, and Long-Term Ecological Research Sites (LTER). At these sites, studies of water quantity/quality and underlying hydrologic processes are used to obtain insight into the internal workings of ecosystems. They also provide data bases for the development of conceptual models and hypotheses involving other forest and range environmental issues.

Forest Service research has a well-deserved reputation for conducting long-term studies and amassing long-term data sets. For example, the Coweeta Hydrologic Laboratory and the San Dimas and Fraser Experimental Forests have been sites of watershed management research for over 50 years, and there is an impressive list of Forest Service sites that now have 25-plus years of watershed research and data. The longevity of these sites provides a host of advantages including a framework for conducting both long-term and short-term research, important background data bases, a focal point for cooperating scientists, and knowledge that the sites will be administratively secure for the life of a study. Over the past decade, many of these sites and their associated research programs and data bases have become much more visible due to their use for ecosystem studies.

Issues and Needs

As we attempt to focus on landscape-scale issues such as cumulative watershed effects or environmental issues such as acidification of habitats and global climate change, some research progress will be delayed by limited information on how water moves through forest and range ecosystems and how this movement is affected by land management activities. Forest and range ecosystems are important sources of our Nation's water resources. As concerns over environmental impacts grow, there is a need to better understand how human activities interact with natural processes to impact ecosystems and the water resources they provide. This task is difficult because land-use activities often occur in combinations. Interactions among activities can result in effects that are cumulative through time or that are not predictable when evaluating each land use separately. Evaluation of complex cumulative watershed effects requires an understanding of the interactions among water, soil, vegetation, climate, sediment, organic material, solar energy, and chemicals at several scales representing time and space.

Cumulative Effects of Water Movement Through Watersheds

We need to be able to quantify the movement of water through all parts of a drainage basin. This is particularly important for predicting potential groundwater contamination, flood events, sedimentation, water supply, and water quality changes. It is important to understand the pathways and rates of subsurface flow because they control transport of associated chemicals and nutrients to streams and aquifers. Although there has been progress in describing subsurface flow processes, a much better understanding of the rates and pathways of water movement through soils is essential for modeling soil chemical reactions and quantifying leaching rates in ecosystems. The residence time of soil water before reaching a stream or aquifer is dependent on the pathways followed, and this contact time affects water chemistry. Process-level field studies will be necessary to reveal more about the pathways and rates of subsurface water movements.

Cumulative Effects of Sediment Movement Through Watersheds

Land use affects rates of sediment production

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and transport and can lead to several environmental effects. Soil erosion can decrease site productivity. High suspended sediment loads can degrade municipal and industrial water supplies.

Sedimentation can reduce reservoir storage capacities, smother benthic organisms, and alter riparian communities and associated fisheries. Sediment is generated through the forces of water, gravity, and wind. We need to better understand these processes and the transport of sediment through watersheds to predict the environmental effects of land use activities. Chemical substances, for example, may be adsorbed on suspended or wind-blown sediment particles. If we are to predict chemical movement through a watershed, we must be able to predict the transport of particles carrying them.

Land use activities are directly responsible for modifying rates of sediment displacement from slopes, and each activity affects erosion processes in different ways. Many of these rates have been measured and are predictable based on intensity and type of land use. However, only rarely do we know what the long-term effects of an activity or of sequential activities will be. The Forest Service is involved in a cooperative effort with ARS and several other Agencies: to develop an improved prediction technology. The Water Erosion Prediction Project (WEPP) is based on modern hydrologic and erosion science. However, data to support input parameters are limited for forest and most rangeland situations. Thus, final verification of input values for forest and rangeland soils and management practices will require more intensive study and development of "forest models" to estimate onsite sediment production from forest roads, timber harvest areas, and surface mined lands. Research is also needed to develop better methods for monitoring changes in soil properties sensitive to erosion in order to predict the effect of different management practices on water quality and site productivity.

Cumulative Effect of Nutrient and Toxic Chemical Movement Through Watersheds

Changes in stream chemistry following timber harvesting were not considered a problem until the late 1960's following publication of results from a study on the Hubbard Brook Experimental Forest. Increases in streamwater nutrient concentrations following timber harvesting have been attributed to accelerated nutrient leaching due to exposure of the site to greater than normal amounts of heat and moisture, acceleration of the nitrification process, and loss of uptake following plant removal. These studies have also shown that the changes are highly variable, very site specific, and generally related to the severity of the cut and rate of revegetation of the cut-over area. The rate and degree of revegetation appear to control the longevity of increased nutrient concentrations.

Forest and rangelands are also subjected to chemicals in the form of pesticides, herbicides, and fertilizers applied to protect and promote growth of desirable species. They are sometimes selected as sites for recycling human and industrial wastes in the form of waste water and/or sludge. These wastes often contain nutrients beneficial to plant growth, but they can also contain chemicals that are phytotoxic and can contaminate surface and groundwater supplies. Atmospheric deposition may supply both nutrients and toxic chemicals to watersheds. Mobilization of nutrients and toxic substances raises concerns about water quality changes and the impacts on water supplies and the fisheries resource.

We need to quantify the rates and processes by which nutrients are lost and how they are made available for use by vegetation after disturbance. To prevent overloading and subsequent losses to aquatic systems, more knowledge is needed on rates of uptake by vegetation and on the ability of soils to retain added nutrients. This includes complex biological and chemical processes that govern immobilization and release of nutrients in soils. We need to know the cumulative capacity of riparian vegetation to control sediments, nutrients, and toxins from surface and groundwater transport as a result of management practices. The response of biological communities to changes in water chemistry, temperature, sediment and organic materials, as they relate to patterns of land use, needs to be defined. For disturbed sites we need to understand the geochemical weathering processes involved. These findings must then be tied to knowledge of water movement through soils to understand and predict changes in nutrients and other chemicals reaching streams and groundwater.

Cumulative Management Impacts on Water Quantity

Undisturbed and well managed forested watersheds are generally recognized as primary sources of high-quality water. Many forested watersheds serve as source areas for domestic and industrial water supply. In the highly urbanized Northeast, more than two million acres of land

under the control of municipalities, private water companies, and state and federal agencies are managed as either water-source areas or protection lands for municipal water supply. Because 80 percent of the West's water emanates from National Forests, the Forest Service will continue to play a role in the development and management of water resources. In the West, especially in those states where water shortages are likely to emerge, municipalities are acquiring more senior water rights from irrigators. Thus, local governments are going to play an increasingly prominent role in reviewing land management decisions for water quantity and quality impacts.

Research has demonstrated that timber harvesting patterns and frequencies can be planned to increase water yields. Most increases come from the fact that timber harvesting reduces evapotranspiration and interception losses. Harvesting can also be designed so that effective trapping of snow occurs and enough shade is provided to retard melting in early summer. Thus, the snowmelt period is extended and high springtime peak flows are reduced. This makes more meltwater available for use. If sufficient reservoir storage existed to contain all runoff events, streamflow timing would not be so critical. However, sites for building additional reservoirs are scarce and rarely feasible either from environmental or economic efficiency perspectives. Vegetation management practices offer some promise for lengthening the runoff period and shortening periods of low flows which create problems for instream water uses. We need to address the resource characteristics that make watersheds sensitive to uses affecting water outputs, especially where a potable water supply is involved. We need to be able to predict the probabilities of flows (annual water yields, peak flows, low flows, minimum safe yields) from undisturbed forest lands and how these probabilities change with forest management activities.

Changes in Climate and Chemical Composition of the Atmosphere

Concern over global climatic changes has increased in recent years as our understanding of atmospheric dynamics and global climate systems has improved. One of the most important consequences of future changes in climate could be alterations in regional hydrologic cycles and subsequent effects on the quantity and quality of regional water resources. Models to predict the consequences of climate change on water quantity, quality and timing need to be developed.

The impact of atmospheric deposition on water resources has been well documented in the scientific literature, especially in regards to changes in water quality and impacts on the fisheries resource. Both chronic and acute stream acidification have been shown to be detrimental to aquatic organisms in freshwater ecosystems. The acidification of habitats has been suggested as one of the possible causes of the world wide decline in amphibian populations along with changing global conditions. Amphibians possess a range of characteristics that make them vulnerable to changing environmental conditions and also potential bioindicators of environmental change. Identifying measurable indicators for monitoring changes in environmental conditions will result in beneficial planning tools for future resource management decisions.

Protecting the Water Resource

Societal demands are increasing the need to better predict the consequences of man's activities on the soil and water resource. In order to meet those increasing demands we will need to better understand the basic processes and factors controlling them, and the resource interactions that are site-specific to the particular geographic and climatic conditions. We also need to expand this understanding to describe larger landscape impacts. Testing large-scale, distributed parameter hydrology models with flow routing capabilities, to see if they can adequately represent watershed hydrology of progressively larger watersheds, is one possibility. Success might depend on incorporating GIS technology and results from watershed studies (dealing with hydrologic change following management impacts) to determine if a GIS-based model would be sensitive to effects on hydrologic processes. Deterministic/probabalistic models, as difficult as they may be to develop, offer a good chance for prediction capability with wide application to conditions across the Country. Simulations can be used to scale processes and variables in terms of their importance to integrated watershed behavior and to reveal gaps in information on linkages between watershed processes.

The Federal Water Pollution Control Act Amendments of 1972, The Safe Drinking Water Act of 1974, The 1977 Clean Water Act, The Water Quality Act of 1987, and many State and local regulations have emphasized the need to

protect and improve water quality. Of particular interest to forest and range managers are the Federal Water Pollution Control Act Amendments of 1972 and the Water Quality Act of 1987. The former act established definite goals regarding the Nation's water resources and specifically identified silvicultural activities as potential sources of nonpoint pollution. This Act requires each state to develop methods to control pollutants from such sources. EPA adopted the concept of "Best Management Practices" (BMP's) to control potential nonpoint pollution from forested lands. This term refers to a practice or combination of practices that are determined by a state to be practical and effective in preventing or reducing the amount of pollution generated by diffuse sources to levels compatible with water quality goals. Examples of specific BMP's were identified in the Water Quality Act of 1987 under section 319 entitled "Nonpoint Source Pollution Management Programs". Section 319 requires each state to prepare detailed water quality management plans that identify bodies of water not in compliance with water quality standards because of nonpoint source pollution.

BMP's are optional methods, measures, or practices for preventing or reducing water pollution. Water quality standards, on the other hand, are specific water quality criteria for designated water bodies of a state. Section 303(d) of the Clean Water Act establishes a process for developing water quality-based pollution controls when technology-based controls are inadequate to achieve state water quality standards. The process involves the calculation of Total Maximum Daily Loads (TMDLs) using predictive modeling in order to develop an integrated pollution reduction strategy. A TMDL is the sum of individual waste load allocations (WLAs) for point sources, and load allocations (LAs) for nonpoint sources (NPS) and natural background, taking into account uncertainties with a margin of safety (MOS). The TMDL is generally set at the loading capacity (LC) of a waterbody, which is the greatest amount of loading that a waterbody can receive without violating water quality standards. A water quality standard defines the water quality goals of a waterbody, or portion thereof, by designating the use or uses to be made of the water, by setting criteria necessary to protect the uses, and by preventing degradation of water quality. States adopt water quality standards to protect public health or welfare, enhance the quality of water, and serve the purposes of the Clean Water Act. The latter includes consideration of state waters for public water supply, propagation of fish and wildlife, recreation, agriculture, and industrial purposes.

Are BMP's doing the job they are designed to do? Are BMP's adequately defined? Will land managers be forced into having to use the Total Maximum Daily Load Concept that EPA is considering? Research can evaluate the effectiveness of BMP's under experimental controls but effective monitoring techniques are needed to verify the effectiveness of BMP's under a wider range of conditions. Both surface and groundwater resources are affected. The Amendments to the Safe Drinking Water Act, which were passed in 1986, established a nationwide program to protect groundwater resources used for public water supplies. Wellhead Protection Areas were defined as "the surface and subsurface area surrounding a water well or wellfield, supplying a public water system, through which contaminants are reasonably likely to move toward and reach such well or wellfield." Thus the Act established the concept of protecting some of the recharge areas to these points of public drinking water withdrawal.

The stream zone is generally the most sensitive part of a watershed. The impacts of management are often integrated in the quality and timing of streamflow. Learning to read early signs of stress here will aid in evaluating how much "management" a watershed can take.

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Status of Water Quantity and Quality Program: National Forest Service System

Warren C. Harper

Introduction

The Forest Service is responsible for the management of 191 million acres of public land. In managing these lands for multiple use purposes, water must be maintained in sufficient quantity and quality so as to provide for the protection of identified beneficial uses. The basic responsibility for protection of water quality and for allocation of water available for use resides with the individual States. In managing the National Forests, the Forest Service must ensure that State requirements are met.

In addition to the management of the National Forests, the Forest Service conducts research on water quantity and water quality impacts resulting from forest management activities. This research is carried out by the Research branch. Support to the private forest land owner is provided through State and Private forestry.

While there are other concerns, the water quality constituent that can be most affected by forest management is sediment. Other concerns that can be important include water temperature, nutrients, and dissolved oxygen.

Policy

Forest Service policy is to provide for the protection of identified beneficial uses of water by reducing nonpoint sources of pollution to the maximum extent practicable through design and implementation of land and water conservation practices. At a minimum, Forest Service policy is to comply with State requirements for protection of water quality to the same extent as any non-government entity.

Forest Service policy on water yield is to enhance water yields in water short areas where possible when designing resource management projects.

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Existing Programs

In order to meet agency responsibility for protection of water quality, the Forest Service has developed and instituted a nonpoint source pollution control strategy based on design and monitoring of conservation practices (BMPs). Utilizing past experience and research information, management practices are designed to minimize impacts of water quality. These practices are then monitored to ensure they have been implemented to determine their effectiveness in protecting identified beneficial uses of water. Based in this information, management practice design criteria are changed where they are found to not provide adequate protection, activities may be stopped where unacceptable impacts are noted, and unforseen impacts are mitigated. Beneficial uses, as reflected by water quality standards, serve as the standard for measuring effectiveness of land management prescriptions. This management strategy has been implemented on the National Forests and has been adopted in concept by most States.

In order to improve the management program for water quality protection, there are several topics of concern that need to be addressed. These topics contain technical issues that need to be resolved. Technical resolution necessarily must precede programmatic solution.

Topic 1: Evaluation Criteria. Water quality standards are the current standard for measuring effectiveness of land management prescriptions. These standards were developed primarily for point sources and do not reflect the variability of nonpoint sources. Because of this variability, such a standard is both difficult to set and to measure. More useful evaluation criteria is badly needed.

Topic 2: Antidegradation. The policy of EPA requires that water not be degraded by the discharge of pollutants. Antidegradation is poorly defined, particularly for nonpoint sources. There is a need to be able to define antidegradation in a way that fits the variability of the natural environment.

Topic 3: Modeling. Traditionally, we have used models in research to better understand systems, and in management to assist in making better resource management decisions. The regulator wants a deterministic model to control activities and land use. We either need to develop such a model or demonstrate why it is not possible.

Topic 4: Monitoring. Monitoring provides the feed back link in the nonpoint source management strategy. Without sufficient monitoring, technically defined in such a way that it will provide the necessary information, the management strategy will fail. We have defined three levels of monitoring; implementation, effectiveness and validation. Technical guidance needs to be given to non-traditional types of monitoring.

Topic 5: Conservation practices. Design and implementation of conservation practices is the way in which the Forest Service intends to protect water quality. Because the Forest Service management strategy is predicated on prevention, it is necessary to understand potential impacts prior to conducting activities. In addition, the Forest Service restoration program requires an understanding of the way in which the natural systems respond to treatment. These management requirements require an understanding of cause effect relationships between land management practices and water quality impacts.

Topic 6: Feasibility / Risk. Legislative requirements are that nonpoint sources are to be controlled to the extent feasible or to the maximum extent practicable. While this is primarily a political/management decision, the technical community must provide the information necessary to be able to make those decisions. This requires information on relative impact, cost/benefit and risk. Currently, this information is not readily available, or at least in a form usable by the manager and politician.

Topic 7. Water yield increase. There will be increasing pressure in water short areas for forest lands to supply additional water. While there is substantial information on water yield increases on a site specific basis, there is little information on water yield increases on a regional basis. In addition to quantity increases, there is a need to better understand the relationship between watershed condition and the "extent" of water.

As the lead agency for forestry for the Department of Agriculture, the Forest Service is responsible for forestry aspects of the SCS PL 566 Watershed program. In addition, the Forest Service provides technical and financial assistance to State Foresters and provides technical advice on all forestry related environmental matters related to private land.

Agency Expertise

The Forest Service has approximately 228 Hydrologists and 222 Soil Scientists. This expertise resides at the District, Regional, and National level, and varies from entry level to senior staff specialists.

Data

Forest Service Manual direction requires water quality data to be stored on the EPA STORET system. Many Forests and Districts maintain data storage systems on local computers.

Funding

Funding for the Soil and Water program was as follows:

	FY90	FY91	FY92
Improvements	$32M	$53M	$58M
Operations	$32M	$11M	$ 6M
Inventory	$ 7M	$ 8M	$ 6M

While all this funding cannot be assumed to go directly to water quality protection, most can be assumed to have some positive benefit to water quality.

Status of Water Quantity and Quality Program: Agricultural Research Service

Donn G. DeCoursey

Water quantity and water quality continue to be high priority topics within the Agricultural Research Service program. Current political and meteorological climates tend to dictate specific subjects receiving most attention. Agricultural non-point source contamination of the world's water supplies was, for example, the most recent object of special attention, engendering a Presidential Initiative on Water Quality. Initial effort in this initiative was oriented toward ground water quality, but recent events are focusing more effort on non-point source contamination of downstream surface water supplies. The recent drought in California and other Western States is putting pressure on the water quantity issue. This paper describes the agency's policy, program, capabilities, accomplishments and future efforts in water quantity and water quality research.

USDA-ARS Policy: Water Quantity and Water Quality Research

The Agricultural Research Service Program Plan 1992-1998 specifically defines policies ARS will use to operate and implement its national program priorities. These policies relate to national planning and coordination, determining program content, establishing priorities, program implementation and management, review and evaluation, and international activities. The Program Plan provides guidance for water quantity and quality policies. The Program Plan policy on program states:

1. ARS will balance its efforts between fundamental and applied research to solve technical agricultural problems. Fundamental research produces knowledge that is an essential scientific resource. In their applied research, ARS scientists will draw on that resource to meet the immediate needs of USDA action agencies, other federal agencies, and users of ARS research findings. By maintaining the balance between fundamental and applied research, ARS will fully address the critical problems....ARS programs will emphasize long-term, high-risk research. Interdisciplinary research teams will be formed, reorganized and redirected as needed to ensure that effort is efficiently focused and that the research leads that promise the widest spectrum of benefits are pursued.
2. ARS will concentrate on problems of regional, national and international scope and importance. ARS will not conduct research that can be conducted better or on a more timely basis by industry or other research institutions. Cooperative research by ARS and State and industrial scientists will be encouraged as an efficient means for increasing the overall benefits that accrue from public investments in agricultural research.

Using the policy statement on program content to guide research philosophy, ARS policy on water quantity research can be described as providing national and international leadership in the conduct and dissemination of research on the amount, distribution, use, and movement of water from rain, snow melt or irrigation. Objectives of the research will be optimal allocation of water resources to provide maximum benefit to all users and minimum environmental impact. Research topics include stream flow forecasts, plant use, groundwater recharge, etc.

The ARS policy statement on water quality is similar except that research leadership is attempting to reduce or eliminate water pollution from agricultural land. Thus management scenarios that protect the environment, are economically sound and minimize detrimental effects of implementation will be developed. Research topics include both surface and ground water contamination from point and non-point sources. Initial effort is on non-point sources of groundwater contamination by both nitrates and pesticides, but future work will address downstream surface water quality.

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Existing Program

ARS' existing program in water quantity and water quality encompasses both applied and basic research; it is a mix of modeling and experimental methods that build on the synergism of both methods evolving together. Experimental facilities vary in size from a single plant in a laboratory, a soil cylinder, or rainfall simulator to plot, field and watershed scale systems. Generally objectives of the research are to better understand physical, chemical and biological processes or to determine how and why various management systems respond as they do to perturbations in system inputs or states. Research is also directed at evaluating how the entire agricultural resource base will respond to likely changes in the global atmosphere and climate.

Research relating specifically to water quantity can be divided into basic and applied research. Some areas of overlap will occur as information from basic research is introduced as a component of applied technology. Basic research on water quantity covers all components of the hydrologic cycle:

1. Infiltration and soil water movement as a function of spatial and temporal changes in soil physical properties, macropore structure, layering, surface evaporation, root water uptake, cropping tillage, cover and soil frost.
2. Evapotranspiration as a function of cover crop, soil moisture, temperature, plant population and root distribution.
3. Plant water utilization as a function of crop type, soil salinity, root distribution and soil moisture content.
4. Precipitation characterization for intensity patterns, storm disaggregation, spatial variability, amount and temporal distribution.
5. Snowpack processes as functions of elevation, slope, aspect, cover and age.
6. Spatial variability and how to simulate processes at a range of scales from plot to river basin.

Applied research on water quantity includes:

1. Water harvesting, water supply forecasting, and snow accumulations and melt prediction.
2. Estimation of peak flow rates in stream systems.
3. Surface and ground water interaction.
4. Simulation of plot, watershed, and basin scale hydrologic processes.
5. Development of irrigation systems and management technology to conserve water and better utilize limited resources for crop production.

Water quality research can be similarly divided into basic and applied research with areas of overlap. Basic research is primarily associated with specific chemical or biological processes:

1. Adsorption/desorption kinetics.
2. Volatilization.
3. Pesticide degradation rates, components and chemical properties.
4. Plant uptake.
5. Effects of soil chemical and physical properties.
6. Use of chemical composition as a tracer for water source.

Other basic research has more direct impact on management.

1. Organic matter and nutrient cycling in rangeland systems.
2. Fundamental erosion processes supporting the Water Erosion Prediction Project (WEPP).

Applied water quantity research overlaps basic research with specific agricultural management application:

1. Effects of riparian systems and filter strips on nitrate and phosphate removal.
2. Effects of feedlots, poultry wastes, grazing rates, cropland tillage and management, irrigation systems and management on surface and ground water quality.
3. Plot, field and watershed erosion as a function of management alternatives.
4. Lake and pond water quality determinations.

Encompassing both water quantity and water quality research are several high priority research activities or problem areas that are receiving attention. These include:

1. Operation and maintenance of a large number of plots and watersheds used to research and validate our hypotheses.
2. Remote sensing, geographic information systems (GIS) and large scale experiments designed to enable scientists to handle extensive data bases required in simulating hydrologic processes on large, basin scale areas.
3. Analysis of spatial variability of soil properties, land use, precipitation and other inputs that affect performance of models simulating both hydrologic and water quality processes.
4. Development of decision support systems to

provide farmers, irrigators, ranchers and managers with decision assistance in selecting optimal management practices in the production of food with minimal environmental effects from agricultural chemicals.

5. Development of comprehensive data bases to evaluate effects of management on ground water quality, the Management System Evaluation Areas (MSEA's); and special programs to evaluate effects and ramifications of projected global climate change on agricultural production.

Research Resources

ARS research personnel have site specific research objectives, thus their expertise facilities data bases and funding are unique. Space does not permit a description of each site, thus general comments about each of these features of the ARS research program are presented.

Expertise of Research Personnel

Expertise of scientific and support personnel working in water quantity and water quality research represents nearly all fields of engineering, biology, hydrology and soil science and associated disciplines in crop and rangeland environments. The most strongly supported fields are hydrologic in nature because both water quantity and quality research areas require this knowledge. They can be grouped as:

1. Those dealing with the soil: soil physics, infiltration, unsaturated flow, effects of tillage on soil properties and frozen soil properties.
2. Those dealing with evapotranspiration: microclimatology, plant water uptake, irrigation and micrometeorology.
3. Those involving precipitation: snow accumulation and melt, and rainfall intensity patterns and frequency.
4. Those involving hydraulic processes: overland flow, channel flow, ground water flow, sediment transport, and erosion processes.

Expertise in water quality encompasses soil and water chemistry, pesticide chemistry, biology, microbiology, nutrient and organic chemistry, ecology and week science. The agency also has agricultural and hydraulic engineers, plant physiologists, soil physicists, geologists, nematologists and scientists in other disciplines who work in the water quantity/quality fields. Many of the scientists are also proficient in the mathematical modeling of physical systems, using these models as research and technology transfer tools. The experimental nature of the programs also requires expertise in watershed and plot instrumentation, rainfall simulation and use of sophisticated laboratory equipment for chemical analyses and soil physical property evaluation. Many of the staff are also knowledgeable of stochastic processes, spatial variability, problems of temporal and spatial scale, use of geographic information systems and remote sensing of the state and quality of the environment.

Facilities

One of the most valuable resources among ARS facilities being used in the water quantity and water quality research is the extensive network of research plots and watersheds. As of January 1, 1991, the agency had over 140 watersheds at 17 sites in 12 states well distributed over the country. These watersheds are used in hydrology, erosion, nutrient and pesticide research. Even larger numbers of research plots are used in productivity studies; these are not reported on in this assessment. Watershed instrumentation varies from simple monitoring of rainfall and runoff to detailed instrumentation required to monitor energy balance, sediment yield, or movement of water and solutes through the soil profile of rangelands and all major agricultural croplands.

Data collected at these sites are frequently supplemented with lysimeter data (both volumetric and weighing) for studying precise movement of water and solutes. Many research locations have some of the best nutrient and pesticide chemistry laboratories in the country. The agency also has many specialized facilities for studying processes such as the interaction of ground water with snowmelt and surface water, erosion using rainfall simulators, lake water quality, riparian water and nutrient movement, preferential flow, bacteria and metabolite chemistry. Some laboratories are also well equipped with geographic information and image processing systems and one location has a very accurate laser for field mapping and profiling. The agency also has several facilities with excellent, well-instrumented flumes for stream-flow, sediment transport and hydraulic structure research.

Data Bases

Extensive data bases have been produced by the facilities identified above. Watershed and plot records discussed in previous paragraphs on facilities identify the broad range of other experimental capabilities. Associated with these experimental facilities are numerable records of productivity; erosion and sediment transport; fundamental processes of soil water movement, solute transport, degradation and adsorption; evapotranspiration; and nutrient and pesticide chemistry.

The research watershed data base is very comprehensive. The 140 currently active research watersheds vary in size from less than 0.25 to over 125,000 acres. Table 1 shows the size distribution, lengths of record, and land use of these watersheds.

Table 1. Characteristics of ARS Watersheds

Size		Age		Land Use	
Acres	No.	Years	No.	Type	No.
<10	58	<10	20	Crop	30
10-100	28	10-20	30	Pasture/Range	59
100-1000	20	20-30	42	Mixed	46
1000-10,000	30	>30	42	Meadow	1
>10,000	15			Pasture/Meadow	3
				Woodland	1

Data from these 140 watersheds are a subset of a comprehensive data base from 333 research watersheds over the country, i.e., data from 193 discontinued sites are available. Of the 333 watersheds, 219 have records longer than 10 years and 48 have records longer than 30 years. In the aggregate, data collected at the sites include soils information, land use, break-point, rainfall, runoff, sediment yield, meteorological information, soil moisture, ground water levels, infiltration rates, nutrient and pesticide concentrations. A listing of data available at any specific site can be obtained. Over the years, ARS has operated over 600 watersheds. Obviously not all these data are in the ARS data base, but data from most of the sites are available in some form. However, data from many of the older sites are limited.

Funding

Funds available at ARS locations on water quantity and water quality research are presented by topic areas in Table 2. The dollar figures presented in the table are approximate figures as of this data, net to the location and do not include administrative overhead. Research in each of the topic areas is oriented toward understanding, prediction, and control of physical, chemical and biological processes as influenced by management practices that include application, technology, cropping practices and where applicable, formulation. Engineering works and model development are also part of the research.

Accomplishments in the Last Five Years

Accomplishments of a scientific nature generally evolve over a period of years; thus many of the items discussed here had their origins many years ago. In some cases recent testing and use of technology confirms its applicability. In this section, accomplishments have been divided into several categories.

Improvement in Knowledge of Hydrologic Processes

Recent development have improved our ability to characterize and analyze historic records of

Table 2. ARS Funds expended in water quantity and water quality research in millions of dollars.

Water Quantity				Water Quality			
Water Cycle		24.4		Water quality mgmt/prot		9.3[1]	
water cycle	1.9			pollutant identification	0.2		
precipitation	0.9			pollutant source	5.1		
snow, ice, frost	1.0			pollution effects	0.4		
evapotranspiration	2.9			waste treatment proc.	0.6		
streamflow	0.2			disposal of waste water	0.1		
groundwater	2.0			water quality control	2.9		
soil water	4.7			Water Quality		41.3	
lakes	0.4			biocontrol	6.7		
water & plants	4.5			nitrates in groundwater	12.2		
erosion & sedimentation	4.9			pesticides in groundwater	12.7		
chemical processes	1.0			salts & toxic elements in groundwater	1.3		
Water supply augmentation		5.2		nitrates in surface water	1.6		
Water management/control		6.0		pesticides in surface water	1.8		
Water resources planning		0.1		sediments in surface water	3.4		
Data base development		0.3		salts & toxic elements in surface water	1.6		
Engineering works		0.5					
Total			36.5[1]	Total			50.6

[1] These items, which total $45.8 million, were obtained from the Committee on Water Resources Research. The 41.3 figure is ARS internal coding. These figures are not independent of each other.

precipitation. These developments include models of the internal intensity patterns of storms. Several models are also available to aid in simulating long sequences of weather phenomena including precipitation, solar energy, maximum, minimum and dew point air temperatures, and wind. We have a better understanding of the movement of water, heat and solutes within the soil. Probably of most significance is the importance of macropore flow processes in translocation of nutrients and pesticides within the soil profile. Several models enable this process to be studied more carefully. The effects of frozen soil and freeze/thaw cycles on soil water movement and infiltration is better known. Soil texture, tillage practices, and other management technologies influence soil physical properties, macropore flow features and even earth worm processes in ways now understood much more completely. Root water uptake is also understood better than a few years ago. Knowledge of all of these processes enable us to better quantify the state and the environment within the soil. Improved knowledge of hydrologic processes is, in part, due to development of large numbers of models that collectively enable us to study both the processes and their interactions. Models have also helped with technology transfer to users in other agencies. Development of decision support system concepts enables both new knowledge and technology to be applied in decision making processes.

Remote Sensing, Equipment, and Large-Scale Experiments

Sensors now routinely assess land use surface soil moisture levels, air temperatures, and snow accumulation and melt. These data are now often incorporated into specific models for water supply forecasting and estimating irrigation demand. New equipment supporting ARS research has been developed; one instrument automatically monitors disc infiltrometers and another helps map the

terrain and surface vegetative conditions. Large scale experiments such as "Monsoon 90" provide extensive data bases for complete water and energy balance of basin scale areas.

Effects of Management and Climate Change on Hydrologic Response

The new Management System Evaluation Areas (MSEA's) in the Midwest will provide an extensive data base for studying effects of management on potential for nitrate and pesticide contamination of surface and ground-water supplies. A variety of crops and crop rotations have been found that scavenge nitrate before it leaves the root zone or migrates into surface water supplies. Research data have also shown that increased levels of CO_2, projected for the future, are likely to increase production at slightly elevated water demand. Some recently developed models have been used to project changes in water supply and hydrologic response as a result of projected climate change.

Future Direction

Research in the next few years is, to a large extent, dictated by current research and questions raised. However, political pressure and current national and global policy issues also play an important role. Thus, we will see continued emphasis on water quality and assessments of global climate change. This is already obvious from the structure of this workshop. In the future we will see a holistic-systems approach to solving problems of agricultural production and maintenance of environmental control. The holistic approach will incorporate all aspects of soil, water, the atmosphere and economics of solutions.

Continued emphasis in water quality research will center on areas critical to the environmental impacts of point and non-point sources of agrichemical pollution. Macropore flow, its simulation and significance is one topic area. A related areas is further research on the vadose zone that lies between the root zone and the groundwater table; continuity between the soil surface and the groundwater table is needed. Research and data collection at the MSEA's will continue. Close working relations with model development efforts will provide research guidance and model validation. Thus we will see continued development of the basin scale version of the WEPP model. Interactive effects of both temporal and spatial scale becomes extremely important in large system simulation, thus there will be more research on scale and how to appropriately simulate the hydrologic processes and their interactions at a range of scales. We will also see hydrologic and water quality evaluations of "most likely" changes in climate.

Research is needed to evaluate and support continued improvements in management system. This includes additional work on effects of tillage, sustainability, and development of environmentally effective production systems. More emphasis will be placed on effects of livestock management systems on surface and subsurface water quality. Improved methods of managing surface-water impoundments to minimize effects of both nutrient and pesticide contamination will be researched using both models and experimental studies.

New focus on large-scale research topics will require additional large scale experiments and increased use of GIS and remotely sensed indices of hydrologic properties and system inputs. Large scale research will also require accelerated research on development of models of hydrologic processes with appropriate balance between temporal and spatial scale. Of particular importance is the issue of mixed land use and evaluation of effects of lateral distribution of sources and sinks of nutrients and other pollutants in estimating downstream response. Increased emphasis on decision support systems, powerful technology transfer tools, will be needed to enable the user (SCS, FS, consultants, farmers, ranchers, and others) to use the improved technology in effectively managing agricultural resources.

Cross-cutting Topic Areas Related to Water Quantity and Quality

The ARS research described in the preceding paragraphs identifies important areas that require collaborative efforts between ARS, SCS and FS. These are:

1. Develop and implement effective ways of quantifying the macropore features of the nation's soils as a function of land use, tillage and soil moisture state.
2. Collectively develop and validate models that can simulate effects of land use distribution on the hydrologic and water quality response of large mixed land use watersheds. The issue of scale is important in this subject because of effects of spatial variability in inputs and states of the system. We need the ability to fill the knowledge gap from field to watershed to basin scales.

3. Identify projects utilizing respective expertise to address aquatic ecosystems problems, including agricultural chemical fate and ecological impact on lakes, streams, reservoirs, and estuaries (e.g., Chesapeake Bay).
4. Develop data bases to compare agricultural management systems and evaluate ecological impacts on soil, water and air quality.
5. Develop models that do a better job of coupling surface and groundwater systems (both water and agricultural chemicals) at a range of scales.
6. Continue development of decision support systems that include an economics component and environmental concerns.
7. Develop adequate model maintenance and technology transfer capabilities.

Status of Water Quantity and Quality Program: Soil Conservation Service

Wildon J. Fontenot

Purpose of Presentation

The purpose of the presentation is to identity common water quality and quantity topics that USDA should promote in the 1990's and beyond.

Introduction

The content of this report centers around SCS's activities in water quality and quantity with emphasis since the inception of the Secretary's Water Quality Initiative. Particularly it deals with:

-Policy
-Description of existing programs
-Agency Expertise
-Data base
-Funding base
-Accomplishments

Policy

SCS has been involved with water quantity and quality from its inception. PL-46, SCS's organic act, designated the Conservation Operations Program to:

-Reduce soil erosion
-Help solve soil, water and agricultural waste management problems
-Bring about adjustments in land use as needed
-Reduce damage caused by excess water and sedimentation

That's going back a little more than 5 years, but I present this just to make the point that SCS has been involved in water from it's inception. Although erosion has been our primary focus, we have done significant work in agricultural water management -- flood prevention, drainage, irrigation water supply and management, and animal waste. We have even furnished assistance to rural communities in municipal and industrial, and recreation water supply.

Other significant policy setting legislation and documents include:

-Resource Conservation Act
-National Conservation Program
-Food Security Act
-National Conservation Program
-Food, Agricultural, Conservation, and Trade Act

The last two have had the most impact in directing us to do water quality work. Of course, the President's and Secretary's Water Quality Initiatives have certainly given great impetus to our agency's activities.

More specific policy of SCS is contained in USDA's NPS Water Quality Policy, SCS's General Manual Part 401-WQP, and National Bulletin 130-8-3 addressing ground water.

I will not discuss these any further since the Five Year Plan reflects their intent.

Description of Existing Programs

SCS's water quality thrust as reflected in its Five-Year Plan is to provide the best available technology and information to rural and urban decision-makers so that they can respond voluntarily and independently to inform water quality concerns and State environmental requirements.

The objectives are to increase technical assistance, help states implement NPS pollution programs, evaluate pollutant loads, plan and implement a system of conservation practices, and evaluate the effectiveness of this assistance.

The action items in the plan fall under two categories -- new actions under the water quality initiatives and redirection of ongoing programs. The new actions include demonstration projects, hydrologic unit areas, regional programs, technology development and data base development.

Ongoing programs consist of:

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-Conservation Technical Assistance (CO)
-Great Plains Conservation Program
-Rural Abandoned Mines Program
-Small Watersheds Program
-River Basins Program
-Resource Conservation and Development Program
-Rural Clean Water Act
-ASCS Special WQ Projects

I have more information on program implementation, but since my time is limited, I'll hold this back and see what kind of questions you ask during the question and answer period.

From a funding standpoint, SCS's total budget approaches $800 million. About 5 percent of that can be tied specifically to water quality activities. However, some of us in the Service believe that fully a third of the other program activities have a positive effect on water quality and quantity.

Technology and Development and Transfer

The rest of this presentation will concentrate on technology development and transfer. I will also talk about technology relating mainly to water quality rather than water quantity. Water quantity and quality are inseparable. SCS's water activities since 1935 have dealt more with water quantity. Although we are not fully automated and technology still needs to be developed on this front, water quality, especially in the areas of pesticides and nutrients, are our areas of greatest need. In other words, we need to get our employees trained to the same level of expertise and with equivalent tools in quality as in quantity. The order of technology development and transfer needs are:

-Nutrients
-Pesticides
-Animal wastes
-Sediment
-Salts
-Biological contaminants
-Other

Within the category of nutrients, nitrogen is the most urgent and phosphorus second. Pesticides are the next highest priority. Animal wastes has been listed as a separate category, but it really is also part of the nutrient picture and warrants high consideration, too. Research and development ongoing in these other categories are important and should continue.

SCS follows 10 steps in planning and implementing conservation systems.

1. Providing information
2. Requesting assistance
3. Determining objectives
4. Developing resource inventory data
5. Interpreting, analyzing, and evaluating resource inventory data
6. Developing and evaluating alternatives
7. Making decisions
8. Documenting decisions
9. Implementing decisions
10. Evaluating and revising

The additional tools and expertise we need to assist in performing steps 4, 5, and 6 can be categorized as follows:

Technology Development Areas
FY-91

ITEM	AMOUNT (Millions)
Planning and Evaluation Procedures	$1.5
Computer Models and Automation	1.0
Practice Standards and Specifications	1.0
Data Bases	1.5
Geographic Information Systems	1.0
Assessment and Evaluation	0.5
Training	1.0
TOTAL	7.5

The majority of our development activities concentrate in these areas. Of the $7.5 million we allocated in FY-91, $6.0 million are earmarked to provide tools in steps 4, 5, and 6.

SCS, more than ever, is stressing the importance of interdisciplinary tools. We have revised our technical guide to include five resources (soil, water, air, plants, and animals) when developing conservation management systems for an area. There are presently 33 work sheets providing a road map through the thought process.

Exhibit A are examples of the work sheets addressing water quality and quantity. They deal with Surface Water Contaminants and the practices of pest and nutrient management. The main item of note is that these are very general and indicate that effects need to be modified to reflect local conditions.

The effects are listed as variable because of climate, nutrient, soil, and vadose zone factors. Our challenge is to find tools that will allow us to quantify the existing conditions and predict the effects of practices so we know when we have arrived at an acceptable level of protection.

We conducted a water quality tools inventory. We divided this inventory into five categories:

-Field assessment tools
-Field computer models
-Hydrologic area models
-Other tools
-Being developed

Exhibit B (Part A, Matrix B and C) indicate that much technology has been developed. This inventory also shows that researchers and model developers have worked in the right areas -- nutrients, pesticides, and sediment.

Let's talk about more successes: We have a good soils data base; through excellent cooperation between Extension Service, ARS, SCS, and private industry we have a good pesticide data base; and, we have created a Climatic Data Access Facility in Portland to get and put NOAA data in a format for specified uses at the Field Office level.

ARS, SCS, and ES are cooperating in developing a user requirements document for water quality modeling. This document will define what the technology must provide the users for two levels of assessment and planning, field and hydrologic area.

Topics for Future Emphasis

Let's review what we have covered so far. If we have:

-Programs that address water quality prior to the Secretary's initiative,
-The Secretary's Initiative that has redirected funding and given impetus to water quality,
-An adequate planning and delivery process,
-Revised our Technical Guide to specifically take water quality into consideration,
-A wide variety of tools to do planning,
-The data bases to provide the input for those tools.

Then what more could we need to get the job done? All is not as well as it may appear on the surface. We have made much progress, but much remains to be done if we are to develop the technology to reach this vision, "Every field office has the capability to deliver assistance adequate to facilitate sustainability of resources for future generations". We are on the right track. We just have to do more and better.

Data Bases

Data bases need to be completed, comprehensive and in a format usable by all action agencies. Without sound data adequately quantifying and qualifying the natural resources, the end decisions will not be creditable enough to encourage sufficient voluntary application of recommendations.

Model Development

Water quality is a complex subject area involving too many variables to be planned without the use of computers. Although there is a multitude of models, the level of accuracy in modeling real situations it too low to make them useful for other than providing general directional type of indications. Even within the subject area that they address, most models do not do all things well. We need to analyze models for their strengths, and pick the best of the best. By use of expert systems, we need to build a "mother model" that is so user friendly that it will be as easy as getting money from an ATM.

Effectiveness of Treatments

More research is needed to determine the effectiveness of treatments. When we consider five resources, we know that there will have to be tradeoffs. There will also be levels of risk involved in choosing some treatments over others. With more knowledge, risk could be reduced and treatments providing more balance among resources would gain acceptance.

Decision Support Systems

Our pluralistic society places many diverse and competing demands on our natural resources. Our sister agency, the Forest Service, has experienced this more than we have because they administer public land. However, if we look at the trends and listen to the talk about regulating non-point pollution and how agriculture keeps coming up, we will need the capability to do quick and comprehensive analyzes of changes within given

areas. We will need planning tools at the field level and regional level that optimize within given constraints resource conditions.

Development of New Treatments

Although we may think of the farmers as the producers of our food and fiber, they are also the managers of a large portion of our environment. We need to gain more knowledge and help them incorporate new treatments in their systems.

We have already identified some of these treatments--integrated pest management, constructed wetlands, riparian zones, filter strips, and sustainable systems.

Facilitated Workshop Session: Water Quantity and Quality

The participants of the workshop were divided into four working groups, one group for each of the four issues, with representation from each of the agencies. The overall charge to this working group was to explore the possibilities for developing interagency cooperation within the Water Quantity and Quality issues. More specifically the working group was to:

1. Determine important **topic areas** that are common to all four agencies, prioritize the topics and develop a rationale explaining why the top 3 to 5 topics are important.

2. Develop a **vision** for the future direction of water resource programs, including identification of research and technology transfer needs and organizational needs and a brief vision statement.

3. Identify and prioritize any major **barriers** to strengthening interagency cooperation.

4. Develop a list of **recommendations** to implement the vision statement and strengthen interagency cooperation.

Each work group was assigned a trained facilitator to assist the group in reaching a consensus and a recorder to document the working groups process and outputs. The outputs of each working group were typed at the end of the day and made available to the working groups the next day and to all participants at the end of the workshop during the wrap-up discussion session. We wish to thank the facilitator's and recorders for outstanding efforts during the workshop.

Lead Facilitator: **Dave Miller**, Forest Service Information Systems, Washington D.C.

Water Quantity/Quality Facilitator: **Tom Clifford**, Forest Service, Washington, D.C.

Recorder: **Gerald Flerchinger**, Agricultural Research Service, Boise, ID.

Cross Cutting Topics Identified

I Need of basic knowledge for quantifying fundamental hydrologic and biogeochemical processes and linkages for different size areas.

II Prediction and assessment of the effects of management practices on water quantity and quality over different size areas.

III Viable management practices that enhance and maintain the integrity of water resources.

IV Complete and transferrable (interagency) data bases that exhibit qualities of accessibility, credibility and maintainability.

Cross Cutting Topic I

Need of basic knowledge for quantifying fundamental hydrologic and biogeochemical processes and linkages for different size areas.

Rationale:

Many of the fundamental hydrologic and biogeochemical processes need to be better quantified. A quantitative understanding of the processes and linkages will provided a knowledge base for other research and management efforts. This is an important cross cutting issue because the different agencies, with different responsibilities, manage at varying spatial scales and points in the landscape. A quantitative description of these processes and linkages would aid in evaluating management impacts on designated uses and facilitate cooperative planning and implementation.

Current Situation:

- Exchange of scientific information is up to individuals.
- Cooperative research works well only at field level.
- Each agency operates independently with respect to data transfer and communication systems.
- USDA initiatives are coordinated at the agency level.

Vision Statement:

A coordinated interagency plan to facilitate quantification of hydrological and biogeochemical processes is developed and updated annually; products to research/technology transfer are integrated across agencies; and, a truly cooperative atmosphere between agencies is developed.

Research and Technology Transfer Needs:

- Technology to route sediment movement from its source through channel systems and reservoirs and to assess its impact, including effects of flow modification.
- Fate, transport and effect of pesticides, heavy metals, and other man-made chemicals (organic and inorganic).
- Nutrient deposition and remobilization with emphasis in the vadose zone.
- Fill in gaps in knowledge about nutrient cycles.
- Characterization of preferential flow and its impacts.
- Complete linkage between the surface and water table.
- Effect of geomorphic scale on flow and biogeochemical processes.
- Thresholds for water quality and quantity on stream channels and aquatic systems.

Organizational Needs:

- Improved exchange of scientific information. Recommend improvement of CRIS and follow ups workshops by topic area.
- Commitment by upper administration to facilitate cooperative research.
- Departmental commitment to compatible communication and data transfer systems.
- Departmental coordination of USDA initiatives rather than by agencies.

Barriers:

- Funding and staffing.
- Different priorities and timing schedules between and among agencies.
- Lack of natural resource advocacy groups in comparison to commodity groups.

- Lack of integrity in defining objectives and administering funds.

- Parochialism.

- Communication (geographical distances).

Recommendations:

- Develop interagency problem-oriented working groups of field level specialists to identify and address knowledge gaps in fundamental hydrologic and biogeochemical processes and linkages. These small groups will facilitate development and coordination of cooperative research and facilitate dissemination of research results.

- Expand mechanism to ensure coordination in agency priority setting among Assistant Secretaries. Communicate to Assistant Secretaries' desire of our three agencies to fully cooperate in developing and conducting research on hydrologic and biogeochemical processes. Request Assistant Secretaries to support and aid in facilitating those cooperative efforts.

- Implement information campaign, jointly developed by agencies, to target potential advocacy groups.

- Develop USDA-wide computer communications network.

- Create USDA task force to standardize water related resource terminology and classification.

- Establish and ensure adequate staffing within each agency with technology transfer.

- USDA recognition of successful interagency cooperative efforts.

Consequences and Concerns -

- These reccommendations will require flexibility in funding and staffing.

Cross Cutting Topic II

Prediction and assessment of the effects of management practices on water quantity and quality over different size areas.

Rationale:

Land managers and producers must evaluate a wide range of land use and management practices affecting water quality and quantity. Improved technology is needed to predict the environmental and economic effects of alternative treatments and to assess results. Factors contributing to the complexity of these technologies include natural variability, legal requirements, a wide range of societal demands and the need to integrate physical and ecological processes.

Current Situation:

- Numerous approaches for prediction and assessment are variously applied.

- Agency cooperation has been limited to specific problem areas. There is much opportunity for more coordination.

Vision Statement:

USDA agencies will apply coordinated approaches to prediction and assessment of watershed effects.

Research and Technology Transfer Needs:

Predictive Techniques -

- Assess existing levels of knowledge and models, and assimilate into a balanced transferrable, useful, and efficient technology.

- Interagency effort to identify knowledge gaps.

- Develop next generation of predictive models.

- Better interpretation of model outputs.

Assessment/Monitoring Techniques -

- Use of predictive tools for assessment of water quality and quantity.

- Need for development (FS Research and ARS) and implementation (NFS and SCS) of efficient monitoring systems.

Organizational Needs:

- o Interagency/interdepartmental infrastructure for technology development and transfer.

- o Increased emphasis on technology transfer within FS-Research and ARS, e.g., incentives for technology transfer within performance evaluations.

- o NFS and SCS staff (technology users) need to be available for development and technology transfer.

- o Improved coordination on technology specifications e.g., hardware, software, standard methods.

- o Improved organizational structures for working at landscape (watershed) level, e.g., Coordinated Research Model (CRM) process.

- o Improved communication of research needs, e.g., SCS biannual research needs report.

Barriers:

- o High level commitment and communication within and among agencies are insufficient to promote development and application of predictive methods and monitoring systems sufficient to meet field level needs.

- o Predictive technologies and monitoring techniques have evolved independently to a large degree and may be incompatible.

- o Not enough emphasis on technology transfer for researchers; application personnel lack enough time to receive, screen and apply technologies.

- o Lack of infrastructure within water resource management to convert basic research into usable technology for transfer.

Recommendations:

Barrier - Insufficient commitment from high level administration

National level framework plan (periodically reviewed) to address needs and commit resources, secretary-level water quantity and quality work group (e.g., coordinate research priorities and technology transfer.)

Barrier - Incompatible predictive technologies and monitoring techniques

- o Organize interagency/interdepartment committees of developers and users to be guided by up-front developed documents that define a clear mission, product, due dates, and operating criteria. Steering committee has authority to commit personnel time with plan approved by agency head. (e.g., compilation, combination, selection, update of watershed, predictive models, and coordinate monitoring systems document.)

- o Shift of funds and staffing to address growing needs for predictive tools and monitoring techniques.

Barrier - Insufficient emphasis on technology transfer

- o Communication of results to public and to Congress, especially with respect to public issues, e.g., pesticides, nitrates, ecological health.

- o Research community should give more emphasis to technology transfer, e.g., amend performance element standards, panel evaluation criteria and positive incentives for technology transfer.

Cross Cutting Topic III

Viable management practices that enhance and maintain the integrity of water resources.

Rationale:

Increased emphasis on the development of management practices offers an opportunity to increase the efficiency of production and enhance the protection of water resources. Management practices designed to protect the integrity of water resources need to be improved. Some are still awaiting development, and those that exist need to be more consistently applied. Such practices need to be environmentally, economically and socially acceptable.

Current Situation:

Current practices designed to protect the integrity of water resources do not address all of the

potential effects on those resources. In addition, some practices are not fully effective, and some are not properly or consistently implemented. Moreover, coordination of these practices among, and even within the agencies has not occurred. As a result, the level of protection provided across the Nation is less than we are capable of achieving. Surveys of surface and ground water quality indicate a cause for concern.

Vision Statement:

The American agricultural and forestry community voluntarily achieves non-degradation of water quality and quantity by applying environmentally, economically, and socially acceptable best management practices.

Research and Technology Transfer Needs:

- Research on cultural practices.
- Develop systems specific sets of BMP's.
- Test effectiveness of systems.
- Decisions aids and guidance documents.
- Education and technical assistance programs.

Organizational Needs:

- A research and development task force.
- A technology development task force.
- A technology transfer task force for education, demonstration, technical assistance and financial assistance. All task forces need to include representatives from research disciplines, technology transfer disciplines, education disciplines, agriculture industry, producers, and environmentalists.

Barriers:

- Economic impact of applying conservation systems: not economically viable in short-term, despite long-term benefits.
- Inadequate resources devoted to developing, testing, and disseminating information on systems (sets of practices).
- Lack of educational and technology transfer materials and resources (e.g., demonstrations): State divisions of forestry are not capturing opportunities to demonstrate solutions; and long time lag in getting information printed and disseminated.
- Farm and forestry programs often inhibit producer acceptance of conservation. Agricultural and forest community has come to expect to be paid to implement practices and systems.
- Agri-business systems are not environmentally or long-term oriented; business satisfaction with tradition and status quo.
- Cooperation among USDA agencies in consolidating practices and systems.
- Agencies do not have enough authority to influence decisions on use of practices and systems.
- No policy-setting standards for computer software used in technology transfer.
- Focus is on individual practices without protocol to develop and test systems (set of practices) on various sizes of land units.
- Tendency to insist on more research before transferring knowledge to practical use.

Recommendations:

<u>Barrier - Economic Impact</u>

- Renew agencies' service orientation in providing more on-the-ground help and educating local owners, operators, and dealers.
- Guaranteed low-cost environmental loans and cost sharing to help smaller operations in implementing capital investments.
- Regionally focused research and development of lower-cost environmentally effective conservation practices and systems.
- Develop clear decision aids and guidance documents to promote use of effective and efficient conservation practices and systems.

Consequences and Concerns -

- Adverse effects on federal and State budget.
- Will private banking systems "play ball"?
- Costs of repeatedly updating practices.

Barrier - Inadequate resources to develop, test, and disseminate information on BMP's

- Joint interagency budget initiatives: ARS, CSRS, ERS, FS, SCS, FS, ASCS. Seeking new ongoing money.
- Authorize additional positions to conduct research, perform testing of BMP effectiveness, and disseminate information.

Consequences and Concerns -

Possible painful redirection of funds and people.

Barrier - Lack of education and technology transfer

- Expand on current USDA water quality initiative to increase a real coverage of educational and technical/financial assistance projects, e.g., use Forest Stewdardship Program to install demonstration projects and to provide technology transfer.
- Extend partnership with other Federal, State, and private entities to jointly fund.
- Develop clear decision aids and guidance documents to promote use of effective and efficient conservation practices and systems.
- Change performance appraisal system for research scientists to give technology transfer equal footing with basic research in USFS, ARS, and universities.
- Change agency policies and procedures to allow papers to be published within six months of submission.

Consequences and Concerns -

- Turf battles in activities funded at State level.
- Need for compromise with partnerships.
- Piecemeal, non-uniform, state-by-state programs.

Barrier - Cooperation in USDA in consolidating BMP's

- Each agency designate liaison persons to coordinate across agency boundaries.
- Compile BMP's for major areas of concern within each agency and review BMP's of States, and other departments and organizations.
- Consolidate and refine collective menu of BMP's into USDA-wide menu with regional differences reflected.
- Distribute BMP's within all levels of agencies, disseminate to users, and provide education.

Consequences and Concerns -

- Risk of losing local flexibility.
- Short-term cost in money and people to get long-term gain.

Cross Cutting Topic IV

Complete and transferrable (interagency) data bases that exhibit qualities of accessibility, credibility and maintainability.

Rationale:

Data bases need be reliable, accessible and interchangeable among water resource agencies to facilitate water quality and quantity evaluations and R&D efforts. These data bases are used for a variety of activities including predictive model development and implementation. Current fragmentation of data bases, software and hardware has inhibited efficient use of USDA data. Coordinating data base efforts will: minimize duplication of effort; make more efficient use of USDA data resources; and result in synergistic interactions among agencies. This will develop for USDA users and cooperators a sense of confidence, credibility, and long-term stability.

Current Situation:

- Data bases exchanges are mainly ad hoc between scientists or units.
- Data bases are not coordinated,

comprehensive, inventoried, properly maintained, and universally accessible.

- Data bases are not planned for exchange during development.
- Documentation, verification, and data reduction/computer storage of data bases are not complete.
- Agency computer operating systems vary.
- Data bases are not up to good laboratory practice standards.
- Lack of staff and funds to adequately document, verify, and support data bases.
- Tremendous USDA-wide data bases.
- Many different Geographical Information Systems (GIS) software systems.
- Data security varies.
- Concerns about Freedom of Information Act.
- Long term Ecological Reserve Data sets are standardized.

Vision Statement:

A system of USDA data bases that are complete, transferrable, accessible, credible, and maintained.

Research and Technology Transfer Needs:

- Agency data base inventory.
- Develop common minimum standards for data bases to facilitate exchange.
- Develop standardized data sets.
- Universal software development.
- Compatible GIS systems.
- Completion of data set computerization.
- Automate water resource data collection.

Organizational Needs:

- Interagency (USDA) plan on data base development.
- USDA data coordination group.
- Compilation of agency "good laboratory practices" (GLP) standards.
- Agency data base oversight groups.
- Agency commitment for funding and staffing for data base management, update, maintenance, and storage.

Barriers:

- Agency commitment to maintenance of data base.
- Staff, hardware, software, etc.
- Standards and quality control.
- Proprietary information; client/ agency/individual reluctance.
- Agency organization.
- Data security; altering data bases.
- Parochialism.
- Expertise at individual locations.
- Budget process.
- Contracting.

Recommendations:

<u>Barrier - Agency commitment</u>

- Good public relations people to get message across to department.
- Establish demonstration project.
- Statement of problem to agency head.
- Organize Washington office seminar within/between agencies.
- Interagency position (white) paper.
- Organize data base management groups

within agencies at all levels (some already exist: USFS).

- Utilize members of USGS Water Resources Data Group and agency GIS groups.
- USDA-wide data base committee reactivation.
- Review of data base needs both in-house and external.
- Raise issue with Committee on Earth and Environmental Sciences.
- Provide cost/benefit analysis to agencies/Department.

Barrier - Staff, hardware/software for data base

- Commitment of new or redirected funds.
- Establish demonstration project.
- Major public relation effort.
- USDA data base analysis group.
- Cost/benefit analysis.

Barrier - Standards for data bases

- Better communication in and between agencies.
- Make standard available to interested scientists.
- Determine which organizations are building data dictionaries.
- Determine how far along various organizations are in developing data standards.

General Recommendations For All Topics

- Inform field locations of the USDA water quality and quantity working group coordinating structure for interagency projects.
- Encourage interagency coordination and active participation in research and technology transfer at scientific working level.
- All agency research personnel evaluation guides be updated to include awarding full credit to scientists for technology transfer activities.

INSTREAM FLOWS AND CHANNEL MAINTENANCE

Issue Session

Status of Instream Flows and Channel Maintenance Program: Agricultural Research Service

Kenneth G. Renard, Carlos W. Alonso, Joe C. Willis, Jurgen R. Garbrecht Calvin K. Mutchler

ARS policy regarding instream flow/channel maintenance is uncertain and vague. Senate Document 59 identified channel stability and sedimentation problems as needing attention in all but four of the fifteen major physiographic regions of the country. The four regions that were considered to have no serious sedimentation or channel stability problems are the Northern Great Plains, Great Lakes Timbered Lands, Lake and Till Plains, and the Northeast. However, the resources that have been made available to develop and assess solutions to these problems have never been sufficient to make the progress needed in the eleven regions. The primary center for sedimentation and channel stability research in ARS is the National Sedimentation Laboratory at Oxford, Mississippi. Even at this facility the pressure to address other research priorities, coupled with a lack of appropriated funds for channel stability research has resulted in a steady reduction of effort. Most of the work in other regions of the country has been terminated because of shifts in national priorities and a redirection of resources to higher priority research, or because stream sediments in the experimental watersheds were not of sufficient concern to support the work. The net result is that research on stream sedimentation, gully erosion, and channel bank stabilization in the Agency has reached a historical low point.

A change in the present situation is unlikely unless there is a change in national priorities or strong expressions of concern are voiced by agencies with the responsibility for reducing the environmental and economic damages of sedimentation. The major impetus for expanding ARS research on these problems in recent years has come from the Demonstration Erosion Control Project (DEC) in the Yazoo River Basin of Mississippi. The strong support that the project has received, and the overwhelming evidence that the transported sediments are the result of channel erosion has given this work a high visibility within ARS.

Historically, there has been little research undertaken in ARS to determine the effects of different land uses and land treatments on low flows. In part, this reflects the limited attention that had been given by the agency to the recreational and wildlife aspects of water resources management. However, in recent years, ARS has become more actively involved in research on the effects of stream quality on aquatic ecology. This work is also largely centered at the National Sedimentation Laboratory, and owes its present high visibility to support from the SCS and COE in Mississippi. Some excellent research has been done at other ARS locations but generally in response to specific requests for assistance.

This frank statement is not intended to negate the importance of the subject to USDA programs and societal wishes, but rather to state that the monetary and people resources to address the problems in ARS are limited at the present time. Whereas other program areas of the workshop are receiving considerable societal impetus which results in funding initiatives and policy statements, instream flows and channel maintenance are currently languishing and receiving little emphasis (with the exception of the preciously cited DEC program).

Existing Programs

Existing programs on instream flows and channel maintenance in the ARS 1991 Strategic Plan are not specifically identified in either area 1 for RESOURCE MANAGEMENT or area 6 for SYSTEMS INTEGRATION. Rather the subject is inferred in the sub-problems such as 1.1 (Atmosphere and Climate), 1.2 (Soil), 1.3 (Water), 6.1 (Resource Management: Systems and Models) and 6.6 (Systems Integration). Furthermore, the research includes both applied and basic research that involves a mix of modeling and experimental

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methods that build on a mix of both methods evolving in time. Experimental facilities used to address the problem vary from the controlled facilities such as hydraulic flumes in laboratories such as the USDA Sedimentation Laboratory, to the heterogeneous conditions encountered with experimental watersheds, to the use of remote sensing to develop data bases, to the use of personal computers (PC's) for hypothesis building and testing in analytical models. Thus the facilities range in size from the small laboratory hydraulic flume, a computer, remote sensing instrument, to a rainfall simulator plot, to a large (approximately 100 sq. mi.) experimental watershed (Fig. 1). In general, research objectives involve understanding the physical processes involved and how and why various management systems respond to perturbations in system inputs or states. The research must also consider how the agricultural resource base will respond to climate change.

Instream flows from the standpoint of maintaining wildlife and aquatic habitat have not been addressed heretofore in the ARS research program with the exception of research at the National Sedimentation Laboratory and some research on the effect of upstream agricultural practices on the survival of salmonid embryo by the staff in Fort Collins, Colorado. Research at the National Sedimentation Laboratory on the ecology of watershed channels includes (1) the collection of baseline data on DEC watersheds before erosion control construction, (2) the evaluation of slow release devices on retention structures to provide maintenance flow in ephemeral channels, (3) adaptation and evaluation of channel structures to enhance environmental conditions, and (4) use of constructed wetlands to clean up point sources of pollution, primarily animal waste. On the other hand, flood series frequency analyses have received considerable attention both from analysis of the flood time series on experimental watersheds and from simulation using analytical computer models. It should be possible to use both of these approaches (runoff time series and analytical models) to predict low flow rates and amounts for different flow periods. Tc this point in time, there have been no demands of ARS engineers and scientists for such work except in the Tucannon River where the role of upstream agricultural practices were investigated for its impact on salmonid embryos.

Instream flow maintenance is of major concern to the nonagricultural industry. The hydroelectric power industry is investigating the role of

FIG. 1. ARS Locations contributing to instream flows/channel maintenance.

watershed management for its impact on water quantity. Thus, they are concerned with water yield, low flow relationships, and, of equal significance, on channel maintenance because the sediments from channels have major impact on reservoir storage capacity and generator performance. Whereas ARS has technical capabilities to research some of these problems, the resources and mandate to conduct such research have not been available.

Channel maintenance research programs in ARS suffer from the perceived concept that engineering efforts associated with bank stabilization, grade control, dredging, energy control, etc., are aesthetically unacceptable and destroy wildlife and biological habitat. Thus USDA efforts associated with engineering approaches to watershed management (and flood control and channel maintenance) are not receiving as much support as in the past. Although support for research programs has also dwindled many issues remain unsolved. Success in the DEC project in Mississippi may help attract some additional support in this area.

Watershed planning procedures in U.S. action agencies such as SCS and FS of USDA, the USCOE in the Defense Department, and USDI agencies like BR, BLM, and BIA must include water management as a major factor. Any treatment of channel erosion/maintenance must be based on consideration of the temporal and spatial complexity within the entire watershed, a very complex problem at best.

Most watershed planning and evaluation methods require the use of some type of computer model, a technology for which ARS has considerable expertise and many ongoing efforts. These models, designed for specific and general application deal with watersheds as landscape pieces (grid pieces and/or subwatersheds) or by processes such as upland areas of runoff and erosion, and channel processes composed of runoff routing and erosion and sediment transport.

Unfortunately, the models currently available emphasize upland processes or channel hydraulic processes and such a model providing equal treatment of both is not readily available. As larger watersheds are being evaluated, the upland part of the watershed becomes less significant. For example, measurements on Goodwin Creek, MS, revealed that over 60% of the silt and clay size fraction sediment came from channel erosion whereas practically all sand came from gullies and channels. It is important to note that channel erosion tends to increase with low sediment loads from decreased upland erosion and decrease with increased upland erosion. Thus, erosion control in farm fields and upland areas, such as might result from conservation tillage and/or grassed waterways, may result in excessive channel instability if runoff is not also controlled. Channel erosion damages include instability resulting from steepened banks, over-bank storm flow in reaches where sand and gravel accumulates leading to poor flood plain drainage, runoff pollution and offsite damages. Fortunately, upland programs might be expected to reduce runoff rates and amounts but such may be accomplished at the expense of reduced downstream water supplies.

Upland watershed flood detention structures have been used by USDA in watershed protection programs for a long time. In many states, the water detained behind such structures must be released within a specified time to satisfy downstream water rights. ARS was involved in the evaluation of such a program on the Washita River in Oklahoma. The research was designed to evaluate the impact of flood peak discharge reductions on downstream channel dynamics as well as the net water yield and water quality. Although the research has been redirected to other topics, the results of the work are most significant. For example, although there was an overall decrease of 5% in the water yield, the results were highly variable. Furthermore, the average sediment yield was reduced by over 30% and was also highly variable temporally and spatially.

Man-induced actions associated with dredging and timber removal increased the water yield about as much as the structures reduced it. Flow duration curves at various locations in the Washita River indicated that the downstream locations had lower flows than upstream which probably resulted from a large irrigation withdrawal.

In the same project, channel changes were also observed. In some reaches, a massive erosional change took place with the channel doubling in width, and a channel meander realignment occurring. Some reaches shortened by 40% resulting from some large flood flows in the 1940's and 1950's. The percentage of sand delivered to a channel system appears to increase with the runoff event size, the amount of cultivated land, and the amount of gullying. Channelization also appeared to effect channel stability. Large flows about doubled the channel cross section with deposition downstream eventually scoured out in a 10-year period. The final summary was that the effect of floodwater-retarding structures on the Washita River channel was unclear.

Channel instabilities are a significant problem in many areas of the country. They vary from situations of channel filling by sediment deposits to entrenchment and bank failures associated with erosion within channels. The problems are especially severe along the bluff line of the Mississippi/Yazoo River flood plain where steep gradients promote channel erosion and the low gradients of channels on the flood plain cause the sediment to be deposited. Flood control reservoirs also include deposition within upstream channels.

Technologies for rectification are available including vegetation, riprap and various other structural materials for bank stabilization; grade control structures for bed stabilization; and snagging and debris removal, channel realignment, and river-training structures for increasing sediment and water conveyance. Upland treatments may increase retention time for runoff and thus reduce the flood peaks and associated erosive capacity within channels and limit the delivery of sediment to channels subject to deposition. The Demonstration Erosion Control Project in the Yazoo Basin of Mississippi is designed to demonstrate the effectiveness of existing technology to the solution of channel problems. It provides an excellent opportunity to evaluate a number of rectification technologies over a wide area and possibly to develop new, more effective technologies for specific problems. It also affords an opportunity to determine the effect of channel restoration methods on the environment. In support of this program and to develop more general methods for the prediction and control of erosion, transport, and deposition of sediment by flows within the stream channels, the National Sedimentation Laboratory has several specific research projects:

1. Evaluation of rectifications installed by action agencies (SCS and USCOE) in the Yazoo Basin for channel erosion control and maintenance of environmental quality.
2. Evaluation of various combinations of vegetation and structural methods for stabilizing stream banks.
3. Developing improved predictors for the equilibrium or capacity transport rates of bed material (gravel and sand) by flows within stream channels and thereby to ascertain the potential for sediment control through channel design and flow control.
4. Determining the effects of bank stabilization and grade control structures on the delivery of sediment from stream channels and on ecological parameters.
5. Evaluation of upland treatment to reduce the sediment delivery to streams; to reduce peak flow rates to lessen stream flow erosivity; and to increase the time length of low flow to enhance channel ecology.

Public concern requires our consideration of water quality and other environmental factors in all natural resource research. All rectification technologies must pass the test of maintaining environmental quality and new technologies are needed to improve water quality and ecological parameters in watersheds (see the companion paper on ARS Wetland/Riparian Status Report by Shields and Cooper).

The amount of effort being applied to the above projects is limited and certainly not commensurate with the research needs of the action agencies charged with the rectification of channel erosion problems. An increased effort by ARS to develop of more effective and economical rectification/ maintenance strategy for stream channels is a continuing need.

Channel maintenance research requires channel profile and cross section data that is both expensive and difficult to obtain. ARS personnel at the Hydrology Laboratory in Beltsville, Maryland, have been using some new equipment that holds great promise.

Landscape features related to erosion and hydrology are being measured using an airborne laser profiler. The airborne laser profiler makes 4,000 measurements per second with a vertical accuracy of 5 cm on a single measurement. Digital data from the laser are recorded and analyzed with a personal computer (PC). These airborne laser profiles provide information on surface features of the landscape. Topography, canopy heights, cover, and distribution of natural vegetation were determined in studies in south Texas. Laser measurements of shrub cover along 6.5 km transects were highly correlated ($r^2 = 0.98$) with ground measurements made with line intercept methods. Stream channel cross sections on Goodwin Creek in Mississippi were measured quickly and accurately with airborne laser equipment. Airborne laser profile data were used to locate small gullies in a fallow level field and in a field with mature soybean. While conventional ground based techniques can be used to make these measurements, airborne laser profiler techniques allow data to be collected faster, with a greater density, and in areas that are essentially inaccessible for ground surveys. Airborne laser profiler data can quantify landscape features related to erosion and runoff and is a useful tool

for providing data for studying and managing our natural resources.

Research Resources

Personnel: ARS research personnel with expertise in water resources, while being involved with site specific objectives, have demonstrated the ability to direct their expertise and resources in multilocation and multidiscipline efforts. Past successful efforts that are most notable are the CREAMS modeling work in support of PL 92-500, EPIC in support of the USDA RCA program (PL 95-192), the SPUR modeling effort in support of range resources, and recent efforts such as RUSLE and WEPP to support the 1985 Food Security Act and its successor.

The expertise in these modeling efforts require nearly all fields of engineering, biology, geomorphology, climatology, hydrology, soil science, range science, crop science, and mathematics. These disciplines are available in ARS current programs but their assignment to other priority research does not imply they could work on this program thrust. In addition, experimentalists proficient in field data collection programs are available, but these too are involved in other priority research.

Facilities: The companion ARS report by D. DeCoursey on "Water Quantity and Water Quality" presents an excellent summary of the experimental watersheds currently being monitored by ARS as well as a synopsis of the watershed sizes, data base length, and land use. Unfortunately, those of the watersheds with continuous or even intermittent sediment data are restricted and in most instances, the sediment data record length is less. Table 1 summarizes those experimental watersheds which have some sediment data. Unfortunately, the sediment data inventory does not list the duration of such sediment records, whether the samples are time based (i.e., whether storm total, instantaneous suspended sample, whether the sample is discharge weighted, etc.)

We suspect that data from the 193 watershed locations listed by DeCoursey as discontinued contained only minimal sediment data.

This data base should be most valuable for instream flow analysis. Unfortunately its utility for channel stability and sedimentation analysis is problematic. For example, cross sections and channel profile data along with particle size distributions for the bed and bank material will undoubtedly be needed but not available for the historic data.

Table 1. ARS watersheds with runoff and sediment data.

Size (acres)	Number with runoff	Number with sediment
<10	58	55
10-100	28	25
100-1,000	23	20
1,000-10,000	19	13
>10,000	15	10

Additional facilities such as the hydraulic laboratories at the National Sedimentation Laboratory in Oxford, Mississippi, and the National Soil Erosion Laboratory in West Lafayette, Indiana, will provide the facilities needed to address channel hydraulic problems.

Funding: Funds available at ARS locations for the instream flow-channel maintenance issue are difficult to assess because of the intimate relationship of this research with other water related programs. For example, the instream flows work is not specifically identified in current funding but could be considered a part of the existing $7.1 million program on the water supply and more specifically the 0.2 million for streamflow. Thus the funds available for such analyses are extremely limited.

For the channel maintenance (erosion, sedimentation, channel stability), there is $5.2 million earmarked for control of soil losses and $14.8 million for watershed management/water quality with a reasonable estimate being about $5 million for channel maintenance. Thus an estimate might be that about 0.8% of the ARS budget and 6.5% of the Natural Resources and Environment budgets are directed toward instream flows/channel maintenance research in FY-91.

Accomplishments in the Last Five Years

This report does not permit a complete detailed summary of recent progress. Rather, a few specific examples are presented which may be of greatest

interest to the workshop participants.

Demonstration Erosion Control (DEC) Project on Yazoo River Basin — Research in association with the three agency DEC project in the Yazoo Basin in Mississippi has numerous interesting applications for channel maintenance. For example, in one experiment combinations of vegetative and structural materials were installed on selected reaches on Johnson and Goodwin Creeks near Batesville, Mississippi. Twenty-nine treatment areas were established from 1979 through 1981 on 5,000 linear feet of formed channel banks. Field evaluations are nearing completion and the data collected should be most valuable for testing analytical models of the various treatments.

Runoff from a watershed carries sediment that must be conveyed by flows in downstream channels. Stream channel research has been one of the major efforts of ARS, and measurement of flow and sediment transport rates have been routine parts of research watershed measurement programs. Although the intent of channel measurement has been to determine the quantities of sediment eroded from the watersheds, the associations between the sediment load and channel stability have been identified. Defining the mechanics of sediment transport became a part of the National Sediment Laboratory mission, and the need for rectification of stream channel problems led to the interagency effort known as the DEC (Demonstration and Erosion Control) Project. Recent concern with the environment has greatly increased research on water quality and ecology in the DEC watersheds.

The two major problems in stream channels are erosion of the channel boundary and deposition of sediment within the channels. These are closely related to bed material transport (sand and gravel) and the meander tendency of alluvial streams with low gradients. Bank failures and headcuts are the most obvious feature of local instability. The propagation of bank erosion has been shown to be very sporadic and influenced by the temporal variability of extreme flow events and the spatial variability of bed and bank materials.

Stage frequency functions were developed for four consecutive water years for Goodwin Creek near Batesville, Mississippi. These were used along with the average rating for the transport of sands to obtain estimates of the expected annual delivery of sands by the observed flows. Also, a shift factor to correct the rating for deviations of each ETR sample therefrom was used to obtain the best estimate of the "measured" sand delivery. The measured sand deliveries differ significantly from that expected for individual years. The differences in the average sand deliveries for the four years are primarily due to differences in the amount of rainfall.

The sand-load frequency tends to increase rapidly with increasing stage at low stages and to approach a constant value at higher stages. This suggests that the extreme, but frequent, flow events constitute significant contributions to the sand load. Research at the National Sedimentation Laboratory has resulted in new knowledge of turbulence near channel boundaries, and sand and gravel transport in ephemeral channels.

Effects of Upstream Agricultural Practices on Survival of Salmonid Embryos — A general study to evaluate the potential offsite economic benefits of soil and water conservation measures were conducted for the Tucannon River Basin, Washington, was conducted by the Fort Collins, CO, group with the support and cooperation of the Soil Conservation Service. The offsite economic benefits were based upon a projected increase in the commercial and recreational harvest of salmonid in the Pacific Northwest. The Tucannon River is representative of the overall decline in salmonid rearing habitat which has occurred in the Columbia River Basin as a result of increased agricultural activity over the last century. A physical-process based computer program was developed to quantify the cause and effect relationship between the survival of salmonid embryo and upstream agricultural practices. The alternatives on the spawning and incubation environment of salmonids was emphasized. The quality of this environment affects both the embryo development and the fry emergence from the gravel substrate. The four major program components, and the system design of the computer program, which simulated the percent fry emergence, and the cause and effect relationships between the percent fry emergence, and the upstream soil and water conservation measures were developed.

The sediment intrusion and dissolved-oxygen (SIDO) model developed by ARS for the Tucannon River is currently being adapted to conditions prevalent in the South Fork of the Salmon River in central Idaho under a cooperative agreement with the U.S. Forest Service Intermountain Research Laboratory at Boise.

Streambank Erosion Due to Bed Degradation — Erosion of channel banks causes severe damage to land and adjoining property. This is a common occurrence along many miles of streams

throughout the United States. In many sections of the country, this problem has reached acute stages. Channel erosion is very costly; removing sediment from choked streams and reservoirs in the United States is estimated to exceed $250 million a year. In addition, the loss of prime agricultural land and adjacent property is valued at millions of dollars annually.

Processes of fluvial erosion which operate on the banks of alluvial streams were examined by considering mechanisms of bed and bank erosion and mass failure of drained, homogeneous cohesive banks. These concepts were used to formulate a mathematical model to evaluate bed degradation for the case in which bed lowering causes bank instability. Application of a model to a laboratory experiment verified the behavior of the bed degradation submodel. Analysis of a more complex scenario demonstrated the importance of considering streambank erosion in streambed degradation analyses.

Grazing Riparian Areas — On grazing lands in the Western U.S., cattle access to streams often leads to accelerated bank erosion and channel instability. Although this was the topic of another presentation at the workshop, it is presented here because of the impact on channel maintenance. A recent survey of ranchers and environment groups has shown that grazing riparian areas is considered to be a most important issue of the 1990's. A relatively new component of ARS research in Reno, Nevada, provides a unique blend of biological and physical studies of riparian areas and grazing interactions. Preliminary results provide key answers for the restoration of riparian areas and the interaction and impact of grazing animals in these areas and the watersheds above them. Earlier research on the Reynolds Creek Experimental Watershed near Boise, Idaho, showed dramatic increases in coliform concentrations in streams where the cattle had access to the stream. ARS also has these types of studies in the DEC project at Oxford, Mississippi.

Analytical Models to Simulate Water Resources and Land Management Impacts — Much progress has been made by ARS scientists and engineers in the past few years involving the development of analytical simulation models. Although such models do a fairly good job on the water balance and on runoff simulation, none adequately treat the channel stability in sufficient detail to reflect watershed protection methods, such as channel straightening, spur dikes, and other mechanical methods of alignment, stabilization, and maintenance dredging. Channel erosion control includes bank shaping and mechanical or vegetative stabilization for localized erosion problems and grade control structures to reduce grade and transport capacity of channel flows are also not adequately addressed.

Future Direction

Research efforts involving instream flow maintenance, although nonexistent in current ARS programs, could be initiated with some new funds or an expression of interest from other USDA agencies. Such research might be closely allied to the water quantity and global change thrusts or from cooperative endeavors with agencies outside USDA. The research might involve special analyses of existing runoff data from the ARS experimental watersheds. More realistically, it might involve using simulation models which might then be used to reflect the impact of land use changes, management practices, and global change on water yield/low flow discharge.

Channel maintenance involving sediment transport, channel stability, channel erosion, and agronomic and engineering treatments to enhance channel dynamics and environmental control will continue. The research will be dictated by current research efforts in response to existing technical questions. Specific technical problems include:

1. Sediment transport is still poorly defined. Deviations of actual measurements of transport rates of sand from average trends are large with long time periods. Consequently, estimates of the sand load for unmeasured streams or for single events in even our most intensively observed channels can not be reliably made. Measurements of gravel fractions of bed material load are few, and evidence suggests the gravel accumulation in alternate bars may deflect the flow and cause erosion of the opposite banks. Consequently, control design remains largely an art with almost no basis to define a failure probability. Rectification methods vary in cost, so means are needed to design rectifications to balance construction and maintenance costs with potential losses from failures. Development of new, more economical rectification methods may be feasible. Research is needed to define the relative effectiveness of various protective measure combinations not only in protecting local channel reaches but also in altering the sediment load delivered downstream. Development of a system approach to

channel rectification is needed.

2. The distribution of shear between bed and bank materials and between particles of different sizes is poorly understood. Fundamental studies are needed to clarify these uncertainties.
3. Evaluation of downstream impacts has been restricted mostly to the effects of sediment on stability of channels and filling of reservoirs in relatively small watersheds. Most of this effort has been concentrated in traditionally agricultural areas in the South and Midwest. In addition to climatic variability and hydrologic differences, some areas of the country have influent rather than effluent streambeds which may change the results.
4. The channel dynamic conditions must be incorporated into water resource analytic models in sufficient detail to permit assessing the role of engineering structures and channel heterogeneity in a meaningful way.

Opportunities of Inter-department Cooperation -

1. Aquatic resources include sport and commercial fisheries. The U.S. Fish and Wildlife Service reported that $17.3 billion was spent in 1980 on sport fishing along. The U.S. Forest Service reported that $434 million worth of fish per year were commercially harvested in the Pacific Northwest during the mid-1970's. The number of fish making spawning runs today are less than a third of those observed in the 1970's. Naturally, these and other agencies are highly interested in accurate analyses of cause and effect between manmade sources of water pollutants and the status of the Nation's fisheries.

   Timber harvest and road construction coupled with major storm events and wildfire have all contributed to excessive inflows of sediments into the South Fork of the Salmon River in central Idaho. The Forest Service is currently embarked on a comprehensive research program to quantify the effect of forest land use on sediment yield and the resulting impact in fish resources. This effort could greatly benefit from the assistance of ARS scientists in the development of comprehensive models of sediment yield from large forested watersheds.

   A similar problem currently confronts Alaska in the Tongass National Forest. An undergoing investigation to identify the effects of fine sediment intrusion on salmon habitat has been turned over to private outfits in the absence of federal interest and participation.

   Both the U.S. Fish and Wildlife and the Corps of Engineers are continuously interested in better instream flow analysis techniques to develop flushing flow recommendations for maintaining the quantity and quality of salmonid spawning gravels, particularly in rivers where gravels are in finite supply.
2. The U.S. Federal Highway Administration has initiated a comprehensive revision of the Finite Element Surface-Water Modeling System: 2-Dimensional Flow in a Horizontal Plane (FESWMS-2DH) used by the agency for engineering design and evaluation of highway river crossings. The main objectives of this massive effort are to enhance the capability of the model to handle larger and more complicated flow problems, add the capability to simulate sediment transport and scour around river crossings, and conduct experimental verifications.

   River crossings can be affected by both scour and bed-degradation processes. In contrast to scour, which refers to local and often temporary lowering of bed levels over a short distance, degradation implies an extensive and often progressive lowering of the river bed over a fairly long distance. Whereas scour problems can often be dealt with by local protective measures, progressive degradation may be more difficult to deal with if not detected in time. Consequences may include loss of land, exposure of foundations, streambank failure, loss of embankments and other river works. On the other hand, scour around local structures such as spur dikes, jetties, and bridge abutments can proceed quite independently from the more general degradation process.

   The flow pattern in the immediate vicinity of bridge structures is usually three-dimensional and the result of complex vortex stretching, vortex shedding, and flow separation. This flow region influences the flow field in the river only within a certain distance around and downstream from the structure. This so-called "near-field" turbulence stems partly from generation at the stream boundaries but also from the interaction of three-dimensional shear layers. The turbulent flow in the near-field region can give rise to a very complex sediment transport process which in many instances can only be rigorously analyzed with three-

dimensional models. For practical reasons, the dimensions of the problem can be reduced by analyzing local scour processes along the same two-dimensional, depth-averaging lines currently used in FESWMS. Second, a series of 'ad-hoc' near-field solutions can be developed to simulate those local-scour situations envisioned as most usually present in highway crossings. These 'ad-hoc' solutions would necessarily incorporate reductional flow-field approximations appropriate to each situation but, at the same time, would allow maintaining high horizontal resolution and computational efficiency.

The vertically averaged approximation is usually associated with the notion of a well mixed flow which is not appropriate in situations when suspended and bedload materials move along nonaligned paths. This sedimentary behavior could be adequately treated by averaging separately, the sediment transport equations over the suspended and bedload zones and accurately characterizing the flow pattern within each zone. This approach, however, will require further research on transport of graded sediments under non-uniform, equilibrium conditions.

Outside the near-field regions, the turbulence is governed entirely by the generation at the river bed, and a predominant near-horizontal flow pattern prevails. This region is the so-called "far-field" and it encompasses the river crossing at large where bed degradation and aggradation becomes the controlling factor and computational resolution is not too critical. In this region sediment movement could be simulated by building upon the flow algorithms presently incorporated into FESWMS. In areas farther upstream and downstream, the river morphology becomes dominated by a unidirectional pattern. In these situations it will suffice to route both flow and sediment as one-dimensional processes using standard numerical schemes. The above methodology will obviously entail replacing the present modeling approach by a chain of nested models of increasing complexity.

The Federal Highway Administration is in the process of farming out part of this work to the private or academic sector for a very large sum of money. It is unfortunate that ARS scientists are not encouraged to compete for projects like this. They could not only benefit from the financial rewards but could contribute to a project of national interest, technical expertise and experimental facilities which are not currently available in the private sector.

3. Plans for long-range participation of ARS in the Demonstration Erosion Control (DEC) Project were made at a joint meeting of the Vicksburg District, COE, the Mississippi SCS and ARS in July 1991, at the National Sedimentation Laboratory (NSL). NSL plans of continued research for DEC include: (1) operation of Goodwin Creek Watershed to accumulate rainfall, runoff, sediment yield, and land-use data base; (2) operation of field-size watershed to evaluate conservation systems plot results; (3) final evaluation of vegetation-structural combinations for stabilizing stream banks were accepted. Also accepted were NSL plans to increase research and evaluation of (1) channel stability and construction measures, and (2) water quality and ecology of DEC channels. All of the planned research is cooperative with SCS, COE, Waterways Experiment Station, and USGS.

   Base funds in NSL cover the continuing research in DEC. Part of the proposed research will be funded in FY-92 with soft money from COE and SCS. FY-93 funding from ARS has not been decided.

Summary

Research on instream flows in ARS is essentially nonexistent although an outstanding data base is available from the ARS experimental watersheds to perform some analyses. Research on stream sedimentation, gully erosion and channel bank stabilization in ARS has reached a historical low point. The multiagency (ARS, SCS, USCOE) Demonstrations Erosion Control project on the Yazoo River in Mississippi is a comprehensive research and demonstration project which provides some visibility for the severity of channel maintenance research. Existing research programs, past accomplishments are summarized and future directions for the research are suggested.

Status of Instream Flows and Channel Maintenance Program: Soil Conservation Service

John W. Peterson

Workshop Purpose/Background

A workshop to discuss water resource research on the part of the USDA agencies is long overdue. I must admit to some bias here, as I have long believed that water issues, which should be of primary interest to those of us in USDA serving American agriculture, have been neglected.

It is worth noting that the Forest Service (FS) has its own "in house" research arm, and for the most part, we in the Soil Conservation Service (SCS), depend on the Agricultural Research Service (ARS) to address our needs. Thus, the agencies represented at this workshop have a need to communicate and will benefit from this dialogue.

How I Understand My Role

As I understand my role, it is to provide a "status report" of sorts, laying out what the SCS is doing or may want to do, concerning instream flows. I will be speaking as a Program Manager, and try to give a sense of SCS's current and possible future direction. As a member of SCS's Strategic Planning core group and also a member of SCS's Wetland Policy/working group, I believe I can provide that overview.

USDA Organization

Understanding that this is a research/technology transfer workshop, I would also mention that our USDA organization occasionally gets in our way. If we really want to "speak with one voice" in water resource policy, programs, and research needs, we need to find some way to get these issues in the Office of the Secretary. If there is any U.S. Government Cabinet agency that ought to have an interest in, and be a leader in setting policy in the water arena, it is USDA. For far too long the recognized water leaders have been the Corps of Engineers and the Department of Interior (USDI). Agriculture is lucky when we are invited to the table, and we need to change that. A strategy for having agriculture assume its rightful role in water issues needs to be developed, but not necessarily by this group.

Definitions/Use of Terms

As I was preparing for this talk, I had an opportunity to talk with Dean Knighton of the FS research arm. I was curious about the FS interest in "instream flows/channel maintenance". Dean explained that going back to the FS organic act (2), the FS has had a responsibility to "maintain favorable flow conditions" in streams running through FS controlled land. "Channel Maintenance" to most in the FS means maintaining those favorable flows. When many of us in SCS talk of channel maintenance, we are referring to the techniques applied to keep channels from eroding or repairing degraded stream bottoms and banks.

When many of us in SCS take an interest in "instream flows" it is because our customers, America's farmers and ranchers, are being asked to contribute more water for environmental uses, or because sponsors of a SCS assisted project are required or want to maintain flows for fish and wildlife purposes, maybe as a mitigation feature. One of the benefits that should come from this workshop, is a better understanding of how we in the different agencies define our terms.

Water-Data Sources-Important Issue

Most of the US water data currently available comes from the 1st and 2nd National Water Assessment (NWA) conducted by the Water Resources Council (WRC) about 1975-78, or the 1st RPA water assessment done by the FS (3,4). Incidentally, our SCS specialists are very complimentary of the FS RPA assessment. It may

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be one of the best sources of water data available today, and unfortunately, not well advertised. Our compliments to the FS.

Using these data sources, and looking at gross instream flows across the nation, it appears that about 93% of all US instream flows currently are available for what might be defined as "environmental uses". Obviously, that is not the case in specific basins, particularly in the west. That leaves about 7% of available instream flows for consumptive uses. If 80% of that 7% is used by agriculture, that is 5.6% of the national total. That leaves between 2 and 3% for other consumptive uses, municiple, industrial, etc. Incidentally, we would all do our customers, American agriculture, a big favor if we would not allow people to exaggerate by saying agriculture "uses 80%" of our water. That simply is not true, yet I hear it said far too often.

How is agriculture viewed by the public when it comes to water? Too often I deal with people who think agriculture has all the water it wants, and wastes it! The environmental community (if there is such a thing) constantly cries for more water for fish and wildlife (it is interesting that the data suggests the environment currently gets 93% of all available instream flows). Droughts, such as those experienced in California and Florida recently, send the big, rich urban centers in search of water for purchase. Poor agriculture finds itself squeezed from both sides, environmental and urban. What better way is there for SCS and USDA to serve its customers than by helping agriculture maintain production, and also making some additional water available for other (fish and wildlife, and municiple and industrial) uses? Hopefully, agriculture would also be compensated for any water given up.

I also find it interesting that many educated people don't really take the time to understand the important role water plays in areas they never think of waters impact. Our new SCS Chief, Bill Richards, has a keen interest in conservation tillage and residue management. We in SCS have historically shared in that interest. I enjoy asking "what is the real reason you are interested in conservation tillage?" Invariably, the answer will focus on erosion control. Most people don't think that water could be the real problem, inadequate soil moisture or too much overland flow.

Yes, if there is any cabinet agency in our federal government that ought to be a major player in federal or national water policy (were there any) (5), it ought to be USDA.

SCS Strategic Planning

Like most USDA agencies, SCS tries to see into the future in some structured way. Our strategic planning process uses data from many sources (3)(4), including our own SCS Natural Resources Inventory (NRI) (6). With this information, we assess the status, condition and trends in US natural resource conditions. We take this information into account as we develop our agency strategic plan, a dynamic, ever changing document, that defines issues important in our view of the future. One of the early issues addressed in our strategic plan (7) was deciding the SCS' role in water quality and quantity. I am aware that quality and quantity were addressed this morning. It's interesting to note though, that SCS's leadership believes we need to develop a water management strategy for the agency. Elements of this strategy would include:

- o water quality
- o water conservation
- o flood control
- o wetlands, policy and definitions
- o instream flows
- o drought, mitigation (initiative)
- o water distribution
- o rural water supplies
- o retrofitting existing systems
- o infrastructure conditions
- o riparian areas
- o vegetative water use requirements
- o water quantity
- o stormwater management
- o weather modification
- o wastewater reuse
- o irrigation, sub-irrigation
- o frost control
- o nutrient, pesticide applications

We are not saying that SCS should be very active in all these areas, but we are saying that they are all part of a complete water management strategy, and we need to suggest what our role, if any, will be.

Our strategic plan will have to note the differences between eastern and western United States (US). When we introduce the element of rainfall (east), the whole environment changes. Not much research data is available for water management use in the east. Most of the available research is from the arid west.

Current SCS Strategic Budget Initiative Involving Instream Flows - Water Conservation/Drought Mitigation

One reflection of SCS's current interest in instream flows is found in the agencies FY-93 strategic budget decision paper proposing more work in the area of water conservation/drought mitigation. Our proposal is to improve, demonstrate and implement SCS technological capacities to deliver (short term and mid-range) agricultural water, management-water conservation, and drought mitigation technical assistance to farmers, ranchers, and rural communities, in order to reduce the adverse effects of drought and to effectively reduce the volume of water required for agriculture. These initiatives will protect aquifers, increase instream flows, and enhance the environment. The initiative would consist of five components: soils, database, instream flows, drought mitigation projects, irrigation water management, and retrofitting existing drainage systems for water management purposes (8).

Droughts in the US cause $1 billion worth of agricultural damages in average years. In 1988, there were $13 billion in crop and livestock damages caused by drought. These losses impact the federal budget by reducing tax revenues while increasing the total costs of federal programs. The USDA spent $6 billion in emergency relief programs to respond to the impacts of the 1988-1989 droughts.

Recent droughts would have caused far less agricultural damage if farmers had more diversified and self-sustaining farm management systems, improved grazing systems on private rangelands, more effective soil moisture management systems, and more reliable short term forecasts of soil moisture. New drought prediction and mitigation technologies are emerging. Prudence demands that we develop these technologies and provide them to the agricultural industry and communities.

For 160 years, irrigation has made a major contribution toward providing agricultural profitability and supplying the nation with high quality, plentiful food and fiber, at a reasonable cost. Irrigation is also the largest single user of water in the west and great plains. However, in the last few decades, the major expansion in irrigation has occurred in the more humid regions of the nation for the production of rice, vegetables, other specialty crops, and orchards. Natural instream flows have been significantly diminished as a result of irrigation and other human-induced uses. In addition, many groundwater sources are subject to heavy irrigation pumping and are declining.

Recently, evidence has been accumulating to indicate that the national expansion of irrigation is about over. The total water used in irrigation has actually declined in the last decade, as almost all other water uses, including demands for instream flows, have continued to expand. Transfers from agriculture to non-agricultural uses are becoming increasingly frequent, and agriculture can expect to be required to produce with increasingly limited water supplies. Very little information has been assembled, analyzed, and published on the value of irrigation water on productive irrigated lands, and the implication of transfers of water from these lands. There have been few USDA resources expended to assist farmers and ranchers to understand how they can optimize the use of surface and subsurface waters. Irrigation technology has advanced greatly in the last decade, and SCS, focusing more on cropland erosion control as a result of responsibilities assigned in the 1985 farm bill, has not kept pace with the new technology.

Drought damages will increase in the future as restraints on natural water withdrawals, and transfers of water to non-agricultural uses, reduces agriculture's abilities to deal with droughts. In addition, as water uses become more concentrated, effects on water quality will become more critical.

A more systematic approach is needed at the state, basin, and local watershed levels, to encourage farmers, irrigation, drainage or water management districts, rural communities, watershed organizations, and non-agricultural water users, to adopt technologies that reduce dependence on the available water supplies, if future agricultural productivity is to be maintained, instream flows are not to be further depleted, and drought damages are to be reduced. Technical assistance, financial incentives and improved soil and water data sources will be needed.

SCS Proposal

Our SCS proposal is to start with demonstrations or pilot projects that will identify, formulate, evaluate and encourage measures that can enhance natural streamflows, including recharge of surface and groundwater aquifers, while maintaining essential water supplies for agriculture. These demonstrations could be targeted to the Great Plains states (ND, SD, MT, WY, NE, CO, KS, NM, TX, CA, and FL). Demonstrations will

include plant materials technology such as conservation tillage, residue management and grazing systems, as well as structural systems.

Conclusion

In summary, the components of the SCS proposal would:

1. Develop measures that enhance instream flows for fish, wildlife, natural vegetation and recreation, while maintaining water supplies for essential agricultural and non-agricultural water needs.
2. Assist farmers and small communities by providing drought mitigation and agricultural water management assistance, forecast seasonal drought conditions, and to deliver specific forecasts about rural water needs, supplies, and water and crop management options.
3. Stabilize the water level in critical groundwater basins, and enhance stream flows by providing quality data and technical assistance to improve irrigation efficiencies through improved surface and subsurface water management.

Knowing where SCS believes that future should be, provides many opportunities for research activity. I am anxious to participate in the workshop sessions and discuss the issue areas where USDA might concentrate its efforts.

Status of Instream Flows and Channel Maintenance Program: Forest Service Research

Charles A. Troendle

Much of the current thrust for defining Instream Flow/Channel Maintenance needs in the Forest Service (FS) and in the Rocky Mountain Region is generated by the claim for channel maintenance flows in Division I of Colorado Water Court. The Forest Service has claimed a reserved right based on the 1897 organic act for instream flows in order to maintain favorable conditions for flows. Similar, and expanded claims, are being made elsewhere.

As a result of the Colorado litigation and in preparing for other such litigations; strengths and weaknesses in the understanding of fluvial systems as expressed in our predictive tools have been exposed. However, before delving into the channel maintenance question, one must remember that instream flows are needed not only for channel maintenance but for fishery and aquatic needs as well as basic maintenance of critical riparian and wetland ecosystems. Many of the flow requirements for fisheries and riparian/wetlands maintenance are also met by channel maintenance flows. Fisheries often require a higher sustained base flow while riparian/wetland stability may require occasional overbank flows.

Channel Maintenance Flows - The Problem

In December, 1989, National Forest System (NFS) and FS Research hydrologists met to identify research, technology development and transfer, and training needs for the purpose of meeting the responsibility for maintaining favorable conditions of water flow, including the protection and maintenance of stream channel integrity. Much of what was discussed then, is still appropriate.

The Forest Service must answer questions regarding impacts on stream channels that can result from alterations in stream flow as well as land disturbing activities. In order of answer such questions, hydrologists need analytical tools, and research is needed in order to develop such tools. We need a coordinated, comprehensive research program to improve our knowledge of streams and stream systems, and action to improve the ability to translate knowledge into useful management tools. Action is needed in three areas:

Research -- Studies on fluvial processes and streamflow sediment dynamics in all major climatic and physiographic regions, and for all stream types.

Technology -- A cooperative NFS and Research effort to develop and support analytical tools, update knowledge, and organize needed training.

Training -- A series of short courses to train NFS hydrologists in hydrologic techniques, advance training in fluvial concepts and techniques, and watershed management principles.

Forest management activities can potentially impact water quality, beneficial uses of water, and favorable conditions of water flow. The Forest Service is required to meet water quality protection as defined by the States and by Federal statute, and is required by the Organic Administration Act of 1897 to secure favorable conditions of water flow on lands reserved as National Forests. Existing and emerging soil and water technical issues will have to be resolved in the 1990's if the Forest Service is to continue to meet its resource management responsibilities. Research is gearing up to address some of these questions and NFS is expanding its technical expertise to utilize either emerging or existing technology.

Watershed management is based upon the concept that a drainage basin must be treated as a holistic unit that includes all physical and biological elements. Proper watershed management ensures that the land which contributes flow to the stream is treated in such a way that adverse conditions are not created, and that streams are protected so as to maintain their hydrologic function.

In managing activities on the National Forests, careful attention must be given to potential impacts on identified beneficial uses of water through application of the Forest Service Nonpoint Source Strategy. That strategy consists of design

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of practices that will minimize impacts on water quality (BMPs), monitoring to ensure that design assumptions are correct, mitigation where adverse conditions result, and adjustment of design criteria when practices are found to cause problems. Sediment produced as a result of land management activities must be maintained at a level that can be carried by the stream system. Sediment in excess of this amount will contribute to a reduced hydrologic functioning of streams and a consequent loss in favorable conditions of water flow.

Hydrologic functioning of stream systems can also be adversely impacted by alteration in stream flow volume. Because export of water through diversion can produce changes in the carrying capacity of stream channels, careful attention must be given to the amount of water necessary to maintain those channels. This includes the volume and timing of flows required for adequate sediment transport, maintenance of streambank stability and proper management of riparian vegetation. Import of water in an amount that exceeds the carrying capacity of stream channels can also result in loss of favorable conditions of water flow.

One of our basic responsibilities is to ensure that uses of the National Forests do not disrupt the balance between sediment production and the stream flow needed for sediment movement, thereby providing for "favorable conditions of water flow". When considering proposed uses under special use permitting authority, favorable conditions of water flow must be ensured. Further, during formal water rights adjudication, water as identified for this purpose must be claimed as a Federal reserved water right on reserved lands.

As noted, the strategies to accomplish these goals involve research, technology transfer, and training. A strong link between NFS and Research is vital and a coordinating group should periodically review progress, make proposals, and update other agencies with similar needs. More importantly, a full-time staff of hydrologists is needed to provide liaison between Research and NFS hydrology. An adequate quantitative understanding of fluvial processes and streamflow-sediment transport dynamics for major climatic and physiographic regions are simply not well developed. Often times we are trying to define "in-stream flow requirements to maintain channel stability" when we don't have a good understanding of what is required to maintain that channel system because we do not adequately understand the nature of the dynamic processes that produced the existing system.

Research Needs

Research is needed to better define the role that the amount, range, and duration of flow has on channel slope, width, and depth development in various stream types with differing amounts and sizes of sediment and bedload. The mechanisms of sediment yield from various land sources to streams and sediment transport through stream networks is extremely complex and is not well defined, either. Without better quantification of the factors controlling fluvial mechanisms, quantification of flows that initiate such things as bedload movement and bank erosion cannot be well defined nor can the threshold levels of flow and sediment loads which will result in a change in channel form or impair fish habitat be estimated.

In order to address and quantify in-stream flow requirements to maintain channel stability or equilibrium and to be able to predict the consequences of a variety of flow changes on that stability; a better understanding is needed on the:

1. Integration of the continuum of streamflow-sediment dynamics and channel form relationships (historical context as well as short-term);
2. Role of bed morphology features on channel stability;
3. Characterization of the physical and biological thresholds of stability in streams;
4. Limits of "acceptable change" (where favorable conditions of flow are not met) with regard to physical (and biological) channel properties;
5. Study the effects of flow regime and streambank composition on streambank stability.

The above items primarily address needs more basic to the channel stability issue. Other needs for which research is required that strongly overlap with concerns about cumulative affects as well as riparian/wetland concerns include:

1. Improved understanding of sediment routing from source areas to streams and through stream networks over time;
2. Integrating hillslope versus channel processes (land form controls on streams);
3. Better definition of sediment transport processes in supply-limited and step-pool streams (bedload transport in relation to course bed elements) and the function of large woody debris on channel morphology;

4. Better definition of rates, timing and role of woody debris input and redistribution in streams, especially upland systems.

The latter research items represent topics significant to current concerns addressing channel stability but they also represent key issues in the cumulative effects, riparian/wetland, fisheries or other priority programs.

Two other needs are:

1. The interaction of "channel maintenance" requirements with other instream flow needs;
2. Improved understanding of stream channel integrity including the development of a consistent spacially and temporarily correct definition.

These issues are more institutional than issue driven. Both are extremely pertinent topics but not necessarily process driven.

Quantification of Channel Maintenance Flows

Although approaches to the problem vary with regions, the dominant procedure for quantifying maintenance flows is housed in chapter 30 of the FS Hydrology Handbook.

The methodology presents a procedure for characterizing the mean annual hydrograph and then estimating mean annual flow, bankfull discharge, and base flow for the quantification point. From those estimates a claim hydrograph is developed and a trigger point identified.

The strengths and deficiencies in the procedure have been identified and chapter 30 is currently being revised to reflect recent improvements in technology. As a result, the procedure has been modified to contain:

1. Improved procedure for verifying bankfull discharge estimates.
2. Trigger mechanism that insures claim is always equalled or exceeded by hydrograph.

In its current form, the methodology allows definition of the flow regime necessary to maintain the existing channel condition. Future research, outlined earlier, will lead to a better understanding of this complex system and perhaps improvement to current methodology.

Status of Instream Flows and Channel Maintenance Program: National Forest Service System

Warren C. Harper

Introduction

The Forest Service is responsible for the management of 191 million acres of public land. The lands that were originally reserved from the public domain were set aside for the purpose of securing favorable conditions of water flow and to ensure a continuous supply of timber. In order to ensure favorable conditions of water flow, the Forest Service has determined that it is necessary to ensure protection of stream channels and stream systems. This requires the consideration of the direct effect of management practices on stream channels, and the indirect effect of practices on the side slopes that supply water to the stream channels. Collectively, this requires that the Forest Service ensure protection to watershed condition.

In protecting the stream channels, it is necessary to provide adequate protection during physical alteration that may result from the use of riparian and aquatic areas. In addition, it is necessary to protect the balance between the sediment available to a stream and the ability of a stream to move sediment. This requires that sufficient stream flow must be maintained so as to maintain this balance. This includes the volume and timing of flows required for adequate sediment transport, maintenance of stream bank stability and proper management of riparian vegetation.

Side slopes must be managed so that sediment loads resulting from management activities do not exceed the ability of streams to move sediment.

Policy

Forest Service policy is to ensure that sediment loads do not exceed the capacity of streams to move sediment through design and implementation of appropriate land and water conservation practices. Water needed in the form of instream flows sufficient to maintain the stability of stream channels for favorable conditions of water flow must be ensured when conditioning special use permits for water withdrawal, and will be claimed during water rights adjudications.

Existing Program

Regions are responsible for ensuring that favorable conditions of water flow are protected on the National Forests. Land management practices are designed utilizing experience and research information to ensure that activitieson the uplands do not adversely effect the hydrologic integrity of stream channels. These practices are then monitored to ensure they have been implemented and monitored to determine their effectiveness in protecting stream channels. Based on this information, management practice design criteria are changed where they are found to not provide adequate protection, activities may be stopped where unacceptable impacts are noted, and unforseen unacceptable impacts are mitigated.

In considering special use permit applications for withdrawal of water, a determination of the amount of water necessary to maintain hydrologic integrity of stream channels is determined. Forest Service handbook on instream flow quantification provides a methodology for determining flow for snow dominated regimes. Special use permits are conditioned to ensure that adequate water is retained for the purpose of maintaining the stream channels. During water rights adjudication, the amount of water needed to maintain channels is claimed as a water right either under State law of as a Federal reserved right.

The Forest Service is currently staffing a new Stream Systems Technology Center at the Rocky Mountain Forest and Range Experiment Station. This group will be responsible for development or technical tools for use by field personnel, development of training programs, and identification of needed research.

In order to improve the existing management program for determining channel maintenance flows, several issues of concern need to be addressed. These issues, or topics, will require the resolution of technical problems.

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Topic 1: Instream flow quantification. Existing instream flow quantification methodology is only available for snow dominated regimes. This covers only a portion of the lands of concern to the Forest Service. In order to meet our responsibilities, it is necessary to move aggressively in development of methodology for other climatic-physiographic areas. In addition, we need to work toward continued refinement of the existing methodology.

Topic 2: Training. There is a varying level of understanding of channel geomorphology by field personnel. It is important to develop and institute a training program to increase the level of basic understanding of channel geomorphology and quantification methodology.

Topic 3: Watershed Condition. Watershed condition as comprised of both channel conditions and slide slope conditions, is directly related to our definition of "favorable conditions of water flow". It therefore forms the basis for complying with our responsibility under the Organic Act. We do not currently have a measure of watershed condition that is sensitive to management activities.

Topic 4: Stream Classification. A stream classification system is needed to improve our ability to manage the water resource. A stream classification system would aid in extrapolation of data collected for a particular stream type, would improve communication between specialists, and would improve communication between specialists and line managers. Consideration should be given to a classification scheme based on observable physical characteristics that would have national application.

Topic 5: Water resource inventory. Management has long needed a means to inventory the water resource but has been hampered by not knowing what is should encompass and what the measurable elements should be. Management would be greatly improved with a means to characterize the water resource. Elements of a water resource inventory would likely include channel maintenance flows, watershed condition, and stream classification.

Agency Expertise

The Forest Service has approximately 228 Hydrologists and 222 Soil Scientists. This expertise resides at the District, Regional and National level, and varies from entry level to senior staff specialists.

Data

Forest Service Manual direction requires water quality data to be stored on the EPA STORET system. Many Forests and Districts maintain data storage systems on local computers.

Funding

Funding for the Soil and Water program was as follows:

	FY 90	FY 91	FY 92
Improvements	$32 M	$53 M	$58 M
Operations	$32 M	$11 M	$ 6 M
Inventory	$ 7 M	$ 8 M	$ 6 M

Work on instream flow is funded primarily out of the Operations portion of the budget.

Facilitated Workshop Session: Instream Flows and Channel Maintenance

The participants of the workshop were divided into four working groups, one group for each of the four issues, with representation from each of the agencies. The overall charge to this working group was to explore the possibilities for developing interagency cooperation within the Instream Flows and Channel Maintenance issues. More specifically the working group was to:

1. Determine important **topic areas** that are common to all four agencies, prioritize the topics and develop a rationale explaining why the top 3 to 5 topics are important.

2. Develop a **vision** for the future direction of water resource programs, including identification of research and technology transfer needs and organizational needs and a brief vision statement.

3. Identify and prioritize any major **barriers** to strengthening interagency cooperation.

4. Develop a list of **recommendations** to implement the vision statement and strengthen interagency cooperation.

Each work group was assigned a trained facilitator to assist the group in reaching a consensus and a recorder to document the working groups process and outputs. The outputs of each working group were typed at the end of the day and made available to the working groups the next day and to all participants at the end of the workshop during the wrap-up discussion session. We wish to thank the facilitator's and recorders for outstanding efforts during the workshop.

Lead Facilitator: **Dave Miller**, Forest Service Information Systems, Washington D.C.

Instream Flows/
Channel Maintenance
Facilitator: **Bill Russell**, Forest Service, Albuquerque, NM.

Recorder: **Roger Kuhnle**, Agricultural Research Service, Oxford, MS.

Cross Cutting Topic Identified

Unstable deteriorating stream channels are causing significant economic, environmental, and social harm. Stable channels must be protected.

Cross Cutting Topic Submitted At The End Of The Workshop

Instream flows need to be quantified for stream channel maintenance, aquatic ecosystem health, wetlands and riparian maintenance, fisheries, recreation and other public trust areas.

Workshop Output - Instream Flows and Channel Maintenance

Cross Cutting Topic

Unstable deteriorating stream channels are causing significant economic, environmental, and social harm. Stable channels must be protected.

Rationale:

Channel instability and changes in flow patterns are causing loss of valuable forest, range, and agriculture land and deterioration of downstream water quality, recreational use, water supply, aquatic habitat, transportation systems, etc.

Current Situation:

- Enabling legislation requires channel maintenance flow to minimize opportunity for channel degradation and loss of carrying capacity.
- Federal and state environmental laws enable agencies to mitigate effects of our actions and to minimize adverse effects of proposed actions.

Vision Statement:

We are using integrated methodologies to describe and achieve stable, desirable, and maintainable channel environments as a function of watershed management.

Research and Technology Transfer Needs:

- Interrelation of runoff dynamics, channel morphology, and human activity on channel stability.
- Improved understanding of sediment routing from source areas to streams and stream systems.
- How does a channel react to different hydrologic and sediment regimes?
- How do we define, change, and manage the hydraulic/hydrologic regime?
- Characterization of physical and biological thresholds and limits of socially acceptable change.
- Develop methodologies to quantify channel maintenance flow requirements.
- Performance and applicability of structural and non-structural practices on channel conditions.
- Need research on social, political, environmental, and economic aspects of channels maintenance.
- Develop methodology for evaluating risk and uncertainty in channel maintenance.
- Interrelationships of wetlands on flow regimes.
- Develop rectification measures to optimize the hydrologic and sediment regimes.

Organizational Needs:

- Need for technology transfer and training.
- Need training on geomorphology of channels.
- Need a feedback loop from applications to technology transfer.
- Multiagency forums for scientists are needed.

Barriers:

- Competing water uses.
- Public perceptions of channel manipulations.
- Funding.
- Database accessibility.
- Agency priorities.
- Interagency communication.

- Turf battles.
- Knowledge of existing databases and computational tools.
- State water rights.
- Distrust of federal agencies.
- Need for large-scale experimental areas.
- Endangered streams are not evident

Recommendations:

Research and Technology Transfer Needs - a) Interrelation of runoff dynamics, channel morphology, and human activity on channel stability; b) Improved understanding of sediment routing from source areas to streams and stream systems; and c) How does a channel react to different hydrologic and sediment regimes?

- Increase funding.
- Change priorities.
- Increase cooperative inter-and-intra-agency efforts - formation of inter-and-intra-agency teams.
- Increase monitoring, data collection, and analysis.
- Increase modeling resources.
- Inventory of existing data, techniques.
- Assessment of magnitude of the problem, utilize expertise in other agencies outside of USDA.
- Form agency data dictionary.

Organizational Needs - a) Need for technology transfer and training; and b) Need training on geomorphology of channels.

- Inventory available training.
- Assess training needs.
- Use USDA Graduate School to develop new training packages.

Organizational Needs - a) Need a feedback loop from applications to technology transfer; b) Multiagency forums for scientists are needed.

- Form interagency conference for technology feedback.
- Share training availability by agency calendars.

Barrier - Competing water uses.

- Request states to reanalyze designated water uses.

Barrier - Public perceptions of channel manipulations.

- Demonstration projects, field days.

Barrier - Database accessibility.

- Develop database catalogue, coordinate with Office of Water Data Coordination.

Barrier - Interagency communication.

- Establish common interagency communication.

Consequences and Concerns -

All four thrusts of this workshop are highly interrelated because the channels are the environment in which the output of all other watershed processes are integrated. Inadequate management of watershed systems may lead to downstream economic and social problems that expose the agencies to public criticism and increased regulation by outside interests.

General Recommendations

- Conduct an interagency assessment of current knowledge and practices in stream channel maintenance.
- Increase interagency cooperation in training, technology transfer, data gathering, analysis, and sharing.
- Utilize electronic mail technology (bulletin boards, etc.) to increase interagency communication.

- o Implement the research program of this workshop.

- o Increase utilization of marketing and public information skills in the area of stream channel maintenance.

Cross Cutting Topic Submitted At the End of the Workshop

Because of the controversial nature of this issue and limited time in the facilitated workshop it was not possible to deal effectively with all topics. This topic is included in the proceedings as an addendum because it generated considerable interest and discussion at the workshop.

Instream flows need to be quantified for stream channel maintenance, aquatic ecosystem health, wetlands and riparian maintenance, fisheries, recreation and other public trust areas.

Vision Statement:

USDA agencies work cooperatively with federal, state, local and private interests to secure flows to protect instream beneficial uses and to address the collective public interest.

Recommendations:

- o Research on instream flow quantification methodologies pertaining to the topic areas.

- o Interagency, interdepartmental and interdisciplinary cooperation on instream flow issues.

- o Assertion of federal water rights for all legitimate purposes.

- o Work cooperatively, when possible, with state water resource agencies to secure instream flows.

GLOBAL CHANGE

Issue Session

Status of Global Change Program: Forest Service Research

Douglas G. Fox, Richard Birdsey, Susan Medlarz, Elvia Niebla, David Sandberg and John Zerbe

Introduction

This paper outlines relationships between the Global Change research activity being conducted on an international scale and the Forest Service component of this program. The discussion centers on the role of hydrology and water resources research within this context. The first section provides a brief introduction to the issue and to the role water resources plays in it. It briefly reviews planning that has been done by the International Geosphere-Biosphere Programme (IGBP), a comprehensive effort organized by the International Council of Scientific Unions (ICSU), and by the US Committee on Global Ghange, the official US representative to IGBP. The second section develops the Forest Service Global Change Research Program (FSGCRP) identifying four program elements, atmosphere/biosphere interactions, disturbance ecology, ecosystem dynamics and human interactions with resource outputs. This section is accompanied by a more detailed program description and listing of national outputs in Appendix 1. The third section outlines specific water related research that is being planned under the FSGCRP. The outline includes a topic breakdown under the four research program elements and includes titles of research being conducted by the Forest Service on these topics. The fourth section looks at water research needs from a slightly different prespective, that of global change researchers brought together to identify modeling needs. The fifth section briefly addresses the FSGCRP modeling strategic plan. This plan represents the framework to bring the research needs and the ongoing research together. The final section summarizes the gaps in research in water that need to be addressed in order to achieve the FSGCRP planned outputs.

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Water Resources and Global Change

Water is a major component of the global change issue. Water vapor is the primary greenhouse gas. Snow and ice exert primal influences on atmospheric and ocean global circulation patterns. Soil moisture is a fundamental variable used to predict global climate. Clouds represent the single largest unknown and uncertain factor in predictions of earth system responses to increased CO_2 and other greenhouse gas concentrations. Water also is the driving force and limiting factor for many if not all of the ecosystems that the government is charged with managing.

Projections of future climates are based on results from global general circulation models (GCM) that include simple representations of the terrestrial surface. This is accomplished with models that simulate the basic mechanics of interactions between atmosphere and biosphere. Vegetation alters the reflectivity, or albedo, of the surface and it provides a transport mechanism for water from below ground into the atmosphere. Stomata act as valves on the water flow depending on the degree of stress that the vegetation is undergoing. Also, vegetation, especially woody species, sequesters atmospheric carbon as it grows and releases carbon as it decays, burns or is otherwise utilized.

Global general circulation models also have simplistic cloud parameterizations. Depending upon the concentration of water vapor and the presence of vertical motion fields, clouds are generated. Since clouds are of a much smaller spacial scale than the 4^{o}-8^{o} resolution of the GCM's, they are so-called, "subgrid-scale" phenomena. As such, clouds are represented only approximately and are among the least certain of global change components.

Other important "subgrid scale" processes are the turbulent exchange of energy and chemicals at the atmosphere surface interface. Turbulent exchange is a complex, nonlinear, chaotic process that not only removes energy and chemicals but also can be a source of these for the larger scales. Because of

this two way transfer, it is not particularly meaningful to drive smaller scale models from the larger scale models. Rather it is necessary for the models to be completely coupled, the smaller scale must be "nested" within the larger scale and complete feedbacks accomodated.

Snow and ice, because they affect the albedo over large portions of the earth's surface, are particluarly significant. They also store water for warmer periods and resupply soil moisture as they melt. Snow and ice cover are dynamically predicted by the GCM's and represent important aspects of climate response in themselves. Snow is of particular significance in the interior west. High elevation snowpack is a primary determinant in the water resources of semi-arid western landscapes.

Because of its central role in global climate determinations understanding the hydrologic cycle is a very high priority research topic. The IGBP (Global Change, Report No. 12, The Initial Core Projects. IGBP Secretariat, Royal Swedish Academy of Sciences, Box 50005, S-104 05 Stockholm, Sweden. ISSN 0284-8015) provides a detailed discussion of the nature of the global hydrologic cycle and the global research planning addressed to aspects of it.

Among the questions they pose are:

1. How does vegetation interact with physical processes of the hydrological cycle?, and
2. How will Global Change affect terrestrial ecosystems?

The conceptualization that IGBP has adapted for looking at the first of these questions is shown in Figure 1. Implicit in this description is the objective of developing simulation models of the biosphere/atmospheric response. Simulation models that have the capacity to represent the significant mechanisms of exchange between the atmosphere and the biosphere. IGBP vision of the terrestrial effects question is divided into three research foci:

1. Physiology of ecosystems, exchange of energy and materials and resulting biomass changes and storage.
2. Dynamics of ecosystems resulting from changes in composition, structure and distribution.
3. Impacts of agriculture and forestry including yield of harvestable products from crops, forests and livestock.

Figure 5 represents the IGBP linkage of terrestrial and atmospheric models. It is clear that the international research community views global change research as primarily constructing complex sets of models that link prediction of future climates with predictions of future realizations of the terrestrial ecosystem. These interrelationships are highly interactive, nonlinear and dependant upon one another. Furthermore, the future realizations of terrestrial ecosystems need to be sufficiently detailed and fine scaled to enable projections of resource outputs and changes in these outputs as a result of changing climate and other social and economic variables.

The US National Committee for the IGBP, chaired by Harold Mooney under the auspices of the National Research Council, has recently developed a strategy document representing the US contributions to the IGBP (Research Strategies for the U.S. Global Change Research Program, National Academy Press, Washington, DC 291p. ISBN 0-309-04348-4). Figure 6, represents the elements of that strategy applied to Water, Energy and Vegetation interactions. It suggests that model construction is supported by field measurement campaigns, manipulation experimentation, and detailed process studies. Model verification is a major effort based on large scale data sets, long-term monitoring studies and application of the models. There are a host of international experiments being planned over the remainder of this decade to address these data requirements.

Forest Service Research Program on Global Change

The Forest Service Global Change Research Program (FSGCRP) takes a complete ecosystem view of the interactions between forests and the atmospheric components that affect forest productivity, health, and diversity. It supports long-term research, fundamental science, monitoring, and the development of predictive capabilities which will address the effects of multiple pollutants and atmospheric change on forest and range ecosystems. FSGCRP is designed to provide answers to the questions the IGBP has formulated, following the strategies developed by the US Committee. In doing this we are a part of a larger picture, namely the total USGCRP. Our part relates to forests and related ecosystems, to resource outputs from those systems and to human interactions with those ecosystems.

The Forest Service will provide the scientific basis to address three broad questions concerning global change and forest ecosystems:

1. What processes in forested ecosystems are sensitive to physical and chemical changes in the atmosphere?

2. How will future physical and chemical climate changes influence the structure, function, and productivity of forest and related ecosystems, and to what extent will forest ecosystems change in response to atmospheric changes?
3. What are the implications for forest management and how must forest management activities be altered to sustain forest productivity, health, and diversity?

Planning for the FSGCRP began in 1986 and has been most recently updated in a May 1990 Program Plan document. The May 1990 Program Plan was developed by Forest Service scientists and land managers, and cooperating scientists from other agencies and the university community. The Plan identifies a new management structure as a strategic response to the international and national global change needs. It consists of a National Program coordinator, Dr. Elvia Niebla and five regional program managers.

The FSGCRP is currently organized into four Program Elements to answer these questions. They are:

1. Atmosphere/biosphere Gas and Energy Exchange (ATBIOX)
2. Disturbance Ecology and Natural Disaster (DISTUR)
3. Terrestrial and Aquatic Ecosystem Dynamics (ECODYN)
4. Integrating Human Activities and Natural Resource Changes (HUMANI)

A detailed description of the program elements and specific deliverables being plannned from the program is included as Appendix 1 of this paper. In the next section we briefly discuss some of these outputs where water related research appears to play a major role.

Specific Water Related Research under FSGCRP

Water research cuts across all four elements of the FSGCRP. An outline of the components of water research that are included in each element follows. Research work that supports each of these elements is listed below each, identified as to RWU, location and performing scientist or RWU leader. This is an approximate listing and should serve as an introduction for our deliberations later this week.

ATBIOX

Hydrologic cycle processes--understanding & modeling

Precipitation

INT-4702 (Moscow)

Mesocale meteorological model - USU cooperators

Interception

Radiation and cloud processes

RM-4452 (Ft Collins)

Cloud cover and radiation related to standard meteorological data - Nikolov, Zeller

Snow accumulation

RM-4301 (Laramie)

Subalpine and alpine snowpack accumulation - Troendle, Schmidt

RM-4452 (Ft Collins)

Snow accumulation in alpine watersheds - Sommerfeld

Snow melt

RM-4452 (Ft Collins)

Alpine snow chemistry, melt and energy balance - Sommerfeld, Bales (U of AZ)

RM-4301 (Laramie)

Subalpine and alpine snow melt modeling - Troendle, Schmidt

Stream flow

RM-4301 (Laramie)

Surface and subsurface flowpath model - Troendle

Application of WATBAL and PRMS within GIS at Fraser Experimental Forest - Troendle, Mowrer, Lullwitz, Smith (CSU) and Livesley (USGS)

Relationships between subalpine hydrographs and climate change - Troendle, King

Water & soil temperature.

SE-435x (Otto, NC)

Soil temperature model - Swank, Vose, Haines (U Ga)

INT-4403 (Missoula)

Temperature distribution - Hungerford

Ground water distribution
Soil moisture
Evaporation and transpiration
RM-4301 (Laramie)
Modeling evaporation from snow surfaces - Schmidt, Gluns (British Columbia Forestry)
Atmospheric Interactions with biosphere
General circulation scale modeling
SE-4455 (EPA-RTP)
Using GCM outputs to develop regional climate predictions for the southern US - Finkelstein
Mesoscale meteorological modeling
NC-4401 (East Lancing)
Application of mesoscale models within and interactive with models to develop regional climate information for fire predictions - Heilman, Simard
PSW-4401 (Fujioka) (Riverside)
Long time prediction of regional climate - Fujioka
INT-4401 (Missoula)
Prognostic mesoscale meteorology modeling using CSU/RAMS- Latham
Local scale meteorological modeling
RM-4452 (Ft Collins)
Diagnostic wind fields - Connell, Fox, Ross (Monash/Melbourne)
Forest canopy meteorology - Miller (U Conn), Fox
Energy balance measurement & modeling.
RM-4452 (Ft Collins)
Energy balance of grasslands - Massman, Zeller
Energy balance of alpine forests - Massman, Connel
Ecosystem modeling
Biomass productivity-stand to regional scale
INT-4154 (Moscow)
Evaluation of global vegetation models - Monserud, IIASA collaborators
RM-4852 (Ft Collins)
Ecosystem response to climate change at the North American contintental scale, including use of TEM, for making RPA projections of global change effects - Joyce
RM-4452 (Ft Collins)
Climate change effects on forests - gap-phase generalized - Nikolov, Moir
RM-4151 (Ft Collins)
Carbon/nutrient interactions and ecosystem response to climate change (GEM model) - Ryan
SE-435x (Otto, NC)
Stand level ecophysiological model for White Pine at Coweeta - Swank, Vose
SE-4455 (Oak Ridge)
Combining UTM and FORET models to model production of loblolly pine as affected by ozone and rainfall on regional basis - Luxmore
Biomass productivity-tree to stand scale
SE-4455 (VPI)
Coupling MAESTRO to growth & yield model (PTAEDA) for loblolly growth - Burkhart
INT-4154 (Moscow)
Effects of variation in temperature and precipitationon Northern Rocky Mountain forest stands as represented in the Prognosis Model for Stand Development - Stage, Monserud
INT-4154 (Moscow)
Disaggregation of Forest-BGC model to individual trees - Korol
RM-4852 (Ft Collins)
Individual tree, species

range, and stand growth responses to climate change using inventory data, gap-phase, timber model (Haynes) and carbon model (Birdsey) for RPA projections - Joyce

RM-4452 (Ft Collins)
Ecophysiology of needle to tree scale interactions - Schoettle

RM-4452 (Ft Collins)
Linkage of physiological tree models to succession (gap-phase) models - Schoettle, Weinstein (BTI/Cornell)

Carbon allocation

SE-4455 (U of Georgia)
Application/adaptationof MAESTRO model predict loblolly pine annual carbon exchange - Teskey, Jarvis (U Edinburgh)

SE-4455 (TVA & Cornell U)
Application of TREGRO model to loblolly pine & norther red oak including nitrogen dynamics - Kelly, Edwards, Weinstein

SE-4455 (VPI & NE-4104)
Using model STAND PIPE to predict carbon balance of loblolly stands - Gregoire, Burkhart, Valentine

SO-4107 (New Orleans)
Linking growth & process models to predict carbon allocation for pine plantations in the southern US - Dell, Thomas, Smith

RM-4151 (Ft Collins)
Gross carbon budgets for forest ecosystems including use of the Forest-BGC model - Ryan

DISTUR

Weather-driven stresses

Erosion

INT-4702 (Moscow)
Sediment yield for roads - Burroughs

RM-4302 (Tempe)
Wind and water erosional processes as related to landscape and ecosystem productivity - DeBano and others

Sediment transport

INT-4302 (Boise)
Sediment intrusion modeling for effects on salmonids - King, Alonzo (ARS)

Channel maintenance

Fire interactions

Emissions

INT-4404 (Missoula)
Emission of trace gases from fire - Ward

Ecosystem effects

RM-4302 (Tempe)
Carbon & Nitrogen interactions in Pinyon-Juniper in response to fire - De Bano, Klopatek

Disturbance modeling

Insects & disease

INT-4154 (Moscow)
Sensitivity to climatic variation of interaction between forest pest models and stand development - Crookston/Korol

Fire effects

INT-4403 (Missoula)
Effects of fire on stand composition and productivity - Ryan, Brown, Keen

Desertification & drought

Ecosystem processes

RM-4351 (Albuquerque)
Utilization of grassland ecosystems in the southwest - Aldon

ECODYN

- Biogeochemical Processes
  - Lake and stream community characteristics
    - INT-4203 (Boise)
      - Population dynamics of salmonids using stochastic life cycle simulation - Lee
    - NC-4301 (Grand Rapids)
      - Process & modeling effects of temperature & atmospheric deposition on streams & lakes in North Central region - Ohmann
  - Chemical composition
    - RM 4301 (Laramie)
      - Chemical transport in subalpine watersheds - Troendle, Stottlemyer (NPS Ft Collins)
    - USGS & NE-4352
      - Variable source-area control of episodic stream chemistry - Lawrence & Murdoch (USGS), Hornbeck
    - NC-4301 (Grand Rapids)
      - Process & modeling effects of temperature & atmospheric deposition on streams & lakes in North Central region - Ohmann
  - Soil water interactions
    - NE-4301 (Parsons)
      - Effects of sulfur deposition on acidity and chemical stability of central Appalachian forest soils - Adams
  - Chemical weathering
    - INT-4302 (Boise)
      - Weathering and watershed modeling (MAGIC/ILWAS) - Clayton
  - Ecosystem nutrient/carbon dynamics
    - NE-4352 (Durham)
      - Effects on site productivity & species composition in mature & managed forests of New England - Pierce
    - RM-4151 (Ft Collins)
      - Water and carbon cycle of old growth forests - Kaufmann
    - NC-4301 (Grand Rapids)
      - Process & modeling effects of temperature & atmospheric deposition on streams & lakes in North Central region - Ohmann
    - SE-4455 (TVA & Cornell U)
      - Application of TREGRO model to loblolly pine & norther red oak including nitrogen dynamics - Kelly, Edwards, Weinstein
    - SE-4455 (Oak Ridge)
      - Combining UTM and FORET models to model production of loblolly pine as affected by ozone and rainfall on regional basis - Luxmore
  - Watershed chemical studies & modeling
    - SE-435x (Otto, NC)
      - Modeling ecosystem sulfur cycling at Coweeeta - Swank, Vose
    - INT-4302 (Boise)
      - Integrated watershed (MAGIC/ILWAS) - Clayton
    - RM-4452 (Ft Collins)
      - Integrated watershed (ILWAS, MAGIC) - Reuss, Massman
    - NE-4455 (USGS & NE-4352)
      - Variable source-area control of episodic stream chemistry - Lawrence & Murdoch (USGS), Hornbeck
    - NE-4301 (Parsons)
      - Effects of sulfur deposition on acidity and chemical stability of central Appalachian forest soils (whole watershed acidification) - Adams
    - NE-4351 (University Park)
      - Cumulative watershed effects on water

resources & municipal watershed management guidelines - Corbett

PNW Land/Water interactions research Program

PNW ecosystems process research program.

PNW/USGS landscape hydrology - Harr, Grant, Leavesley (USGS)

Riparian Dynamics

Vegetation interactions

RM-4551 (Lincoln)

Waterway buffer systems (filter strips) to mitigate sediment & non point pollution from agriculture in the Great Plains

Soil water and moisture

Ground water flow

Biogeochemical interactions

Riparian system modeling

HUMANI

Value of water

Economics of water

RM-4851 (FTC)

Predicting economic and other implications of climate change effects on river basin scales - Brown

Society & cultural significance of water.

Water pollution

Atmospheric deposition.

NE-4301 (Parsons)

Effects of sulfur deposition on acidity and chemical stability of central Appalachian forest soils - Adams

USGS & NE-4352

Variable source-area control of episodic stream chemistry - Lawrence & Murdoch (USGS), Hornbeck

NE-4351 (University Park)

Sulfate deposition gradients and resulting water quality changes - Corbett

NC-4301 (Grand Rapids)

Process & modeling effects of temperature & atmospheric deposition on streams & lakes in North Central region - Ohmann

Point source pollution

FPL-4712 (Madison)

Bioremediation of waste runoff from pulp mills and wood preservation facilities.

FPL-4709

Reduction of effluents from paper bleaching manufacturing processes.

Tuscon Modeling Meeting

At the FS-GCRP modeling meeting in Tucson last November, a group of scientists addressed water related modeling. They developed Table 1 shown below recommending regional priorities for a list of 11 water issues.

They agreed that because of the significant implication of an altered global hydrological cycle associated with a changed climate, water yield or hydrologic models will play a key role in the FSCGRP. At the present time, there are numerous water yield models available that address processes over a wide range of scales. However, key processes essential for global change scenario modeling, such as snow-zone dynamics, are lacking in the present water yield models. Before the existing water yield models can be linked to GCM predictions, **mesoscale atmospheric models are needed to link the GCM predictions to the smaller-scale water yield models and provide the necessary meterological input variables.** In addition, **vegetation effects on water yield are not known at scales larger than the stand level.** The modeling effort within the FSGCRP should address this problem. **The impacts of land usage and topography on hydrological models are not well-known.** A better understanding of these impacts should be developed.

The Forest Service should continue decentralized efforts at developing basin-level water-driven ecosystem models, but **should look for overlap and compare similar models from different locations. Efforts must be increased at linking hydrological models with nutrient availability, forest productivity, and land-use pattern and intensity models.** Water modeling efforts should take advantage of interagency opportunities, where appropriate. Agencies like ARS, USGS, and EPA may provide excellent opportunities for

cooperative water-modeling research.

A considerable amount of effort is needed to improve riparian dynamics models for the FSGCRP. To date, riparian zone issues have been addressed in terms of vegetation maps, ecological classification, inventory, grazing systems, and fish sampling. Some emphasis has been made at looking at large estuarine issues, such as urban and agricultural effects. However, no process models that are dependent on a varied climate or disturbance effects have been developed. **Such models are needed to bolster present preliminary examinations of riparian-zone hydrodynamics. Models that include groundwater flow processes and biogeochemical dynamics will be developed. Models to predict relative fish abundance in relation to stream geomorphology and vegetation structure, and basin-scale water temperature should be developed.** The relationship between riparian vegetation and water consumption should be addressed in future modeling efforts.

In addition to water yield models and riparian dynamics models, **the development of improved soil-water models** should be an essential modeling activity in the FSGCRP. Current models of soil water-water availability work well at the stand and plot level, but **a good understanding of soil-water distributions and processes at landscape levels is lacking.** Improving the representation of soil-water dynamics in current GCMs will depend on how far we progress in gaining a better understanding of landscape level soil-water processes. Soil water availability is also a key factor affecting the growth and yield of forests, as modeled by forest-stand models. However, current representations of soil-water dynamics in these models need to be improved to reflect current knowledge of soil physics. **A key problem will be modifying stand growth models to accommodate the better time scale resolution of soil-water models.**

There are many Forest Service sites that have individual soil-water models, some of which were developed as part of larger basin- or plot-hydrology models. Unfortunately, there has been little coordination of these models within the Forest Service, and less than adequate communication between soil-water modelers and vegetation modelers. **The Forest Service needs better coordination and interaction between hydrologists and vegetation dynamics modelers in order to improve the soil-water components of forest models.**

Strategic Plans for Modeling within FSGCRP

The FSGCRP will develop, evaluate and apply models. In order to:

1. Improve the understanding of basic forest and rangeland ecosystem processes, in particular how they respond to climatic and other stresses.
2. Improve the understanding of atmospheric interactions with forest and rangeland ecosystems, including effects of climate change on ecosystems and ecosystem change on climate.
3. Improve the understanding of how forest management activities and resource outputs will be effected by a changing climate.
4. Provide an improved characterization of forest and rangeland ecosystems to earth/climate system models.
5. Evaluate alternative response strategies and options for mitigation and adaptation by predicting system responses to both global change stresses and management actions.
6. Provide an improved characterization of forest and rangeland ecosystems to economic/policy models. A most important result of this will improve the ability to predict effects of climate on forests so that prospective forest responses can be assessed in Forest Service planning processes such as EIS/EA, Forest Plans, area guides and RPA.

Additionally modeling will be used to aid in the synthesis and integration of research results from the wide array of studies that incorporate global change. It can also help to identify weaknesses in system understanding thereby aiding in identification of priority research.

It should also be pointed out that the modeling envisioned by the FSGCP will be highly interdisciplinary in it's nature. Since the global change issue is rooted in climate, our modeling will focus on aspects of the ecosystem that are influenced by the climate and by human reactions to that climate. However, since all aspects of ecosystems are linked to each other this will not eliminate the need to look comprehensively at the entire ecosystem. Further, since the Forest Service is responsible for the management of vast reserves of federal forest and related ecosystem lands, our modeling can not be limited to the biological and physical aspects of the ecosystem. We must include people. Satisfying the social and economic

demands the US public places on their land based resources are, in large part, why we are concerned with global change. And, since forests play a role in the global balance of greenhouse gases and in the available options to deal with this issue, the FSGCRP must be in a position to evaluate the scientific, economic and social consequences of any proposed alternatives.

Individual scientists, RWU's, and organized research teams within each Program will pursue modeling for all goals identified above. The majority of FSGCRP resources in modeling will be utilized this way. Selection of scientists, RWU's and extramural cooperators and the specific modeling they pursue will be based on the specific Program's plan.

However, there remains a need to: (1) develop models that have broader than regional scope; (2) evaluate generalized process modeling techniques; (3) integrate component models from different regions; (4) synthesize and integrate broad modeling efforts to accomplish complexity and spacial/temporal resolution appropriate to the issue at hand; (5) evaluate models at scales above the region; and (6) represent the FS modeling effort in a corporate manner to national and international clients. It is necessary for the modeling to scale up in an intelligent manner to the global scale. While, specific regional approaches are the most appropriate to understand regional and subregional scale phenomon, many of the interesting scientific and policy questions in global change involve scales well above the regional scale. In order to address these, and to insure that feed back mechanisms are properly included and assessed, regional models need to be developed such that they can operate as components of a larger scale modeling system. This is also necessary because the complexity of the earth system is so great. In order to predict the changing climate it is necessary to properly simulate nonlinear atmospheric/forest exchanges of energy, water and CO_2 as a minimum. Conversely in order to predict effects of climate on forests it is necessary to predict the dynamics of forests. Economic and social decisions will depend on the health and productivity potential of forests as well as on a number of additional complex political factors associated with global conditions.

It is, therefore, necessary to develop a national modeling capability within the FSGCRP. This activity would be charged with the responsibility to work closely with emerging joint modeling efforts such as CSMP, CHAMP and TERRA to accomplish it's work.

The USGCRP Research Strategy recommends the context for terrestrial ecosystem modeling shown in Figure 7. The concepts behind this outline are based on recognition of the disparity of space and time scales between atmospheric GCM's and ecosystem dynamics models (EDM's). They suggest that a "Forcing Module" is needed which performs the tranlation from GCM outputs to those needed by EDM's. Essentially this translation is from short-time, large scale information to local, long-time information. They also suggest that an "Aggregation module" is needed to represent the aggregate dynamics of ecosystem changes from their local, long-time scale form to a short-time large spacial scale format appropriate for inclusion in GCM's. The Land Surface parameterization (LSP) is a biologically static model of biosphere processes that influence the atmosphere (albedo, soil moisture, evaporation, transpiration, etc).

The scope of the FSGCRP modeling effort as outlined in Figure 8, expands the modeling outlined in the strategic plan by adding our concern for outputs from ecosystems. Ecosystem output models (EOM's), for example growth and yield tables, are not presently driven by ecosystem process models. The translation between EDM's and EOM's requires consideration of disturbance phenomona, water and climate all of which interact to affect the outputs. A key component of FSGCRP corporate research will be establishing details of how these phenomona should be linked to provide the proper interfaces between EDM's, Forcing module, Aggregrate module and EOM's. Defining this linkage will establish guidelines for scientists working on subcomponents and ensure that their results will be aggregatable up to the larger system. The aggregration module, yet to be designed, will include both water and disturbance processes and influences to integrate individual ecosystem dynamics models. Ecosystem outputs are also considered from a somwhat broad perspective that includes both the significance of the outputs and how management is involved in the sustainability of those outputs.

Each of the regional programs will be responsible to develop model subcomponents. The hierarchical ecosystem dynamics models most likely will be developed by a large team of scientists loosely coordinated by process and/or scale and across these by ecosystems. The FSGCRP will lead for some of these models. Water models will be more highly coordinated with individual team members working along specific process component lines but within the structure of a particular nationally accepted, hydrologic system

concept. The water component will most likely be coordinated with other CEES activities in water because other agencies have a leading role for this component. The disturbance modelers, again a dispersed team of people, will also be integrated by a national system concept that recognizes subcomponents for each stressor. The forcing module climate system will have relatively fewer component workers but will be closely aligned with atmospheric and large system modeling activities. The S/E system will actually consist of a variety of teams addressing specific resources and, perhaps, planning horizons. Many of these models are developed and simply need to be adapted to global change applications. Thus, we envision a national timber team for RPA, another for Forest Plans, and still another for water in major river basins, e.g. Colorado River. These teams will need to be cross fertilized with the process teams created to work in the natural resource system.

Summary of research needs of the FSGCRP in water research.

The design of all these modules and framework that will provide guidelines on interfaces will be developed by the FSGCRP national modeling team.

Water related research that is ongoing under the Forest Service Global Change Program is very broad. It incorporates basic processes as well as more empirical studies. There is not equal representation in all the variou process subareas but work does generally represent regional priorities. In order to accomplish the stated output of the national program, there are a few major needs that are not being fulfilled.

First, there is a need to look at scaling differences between the tree stand watershed scales most of our research addresses and the 105-105 km^2 areas encompassed by the grid structure of GCM's. This can be accomplished by coupling mesoscale meteorological models with watershed models but there is noone within the program currently working on this problem. Research on larger watershed-basin water yield models capable of incorporating effects of cummulative management and user impacts should be expanded.

Second, considerably more work is needed on the dynamics of riparian areas. Although, riparian represents a small percent of the land area, the significance of riparian areas, particularly in semi-arid landscapes is very high. More basic research is called for on this problem.

Third, coupling combined disturbance influences, eg fire, insects and disease, erosion, with the context of watershed models and scaling then up to multiple watersheds has not yet been done. While bits and pieces of this exist there needs to be greater emphasis on cooperative efforts.

Fourth, the significance and value of water is not being properly accounted for in planning and other cost benefit analysis. Research needs to improve capability to "value" water.

Fifth, a model shell needs to be constructed. This shell would provide the framework for interfacing hydrologic, biogeochemical and physiologically based models of terrestrial ecosystems. Some of the work has been initiated and is being pursued but there is no consensus on how they need to be limited.

Finally, there is a gneral need for greater communication and corporate level planning. Major outputs of the FSGCRP need to rely on water models being integrated into terrestrial ecosystem model frameworks. This will not happen by chance. For this reason FS-GCRP is calling for the establishment of a national modeling activity. This need not be a physically colated group, but rather a national team of researchers willing to work toward a common goal. This team needs to ineract regularly with other, similiar teams from other disciplines. All the teams need to be working toward a common, corporately defined, terrestrial ecosystem model. The design of such a corporative model or modeling shell must be considered a high priority research idea for the coming year.

Atmosphere/Biosphere Gas and Energy Exchange (ATBIOX)

Research emphasizes the linkages and interdependences between ecosystems and global change. The primary thrust is development of comprehensive models capable of addressing both the response of forests and related ecosystems to global change induced stress and their associated feedbacks to the climate system. These models will form a primary link with total climate system modelers, generate improved estimates and predictions of terrestrial components of the global carbon cycle and allow prediction of global greenhouse gas concentration changes as a consequence of both climate change and ecosystem manipulation.

Research under this element includes four major components:

1. Field observations. Research and monitoring takes place on existing

Experimental Forests and Rangelands and more than 200 Research Natural Areas of the Forest Service, and at thousands of established sample locations across all 50 states and Puerto Rico. Periodic observations of carbon, water, sulphur, nitrogen, and nutrient cations are made in the soil, forest floor, and different plant parts in order to understand ecosystem processes, monitor changes, and develop predictive models. Measurements of the atmosphere adjacent to the plants are made to determine biogenic gas fluxes, especially carbon dioxide and methane, and to monitor ozone and acid deposition. Simultaneous measurements of atmospheric and soil physical and biological variables are made under a variety of conditions in order to understand the environmental forces and controls on nutrient cycling and retention, and to correlate changes in gas fluxes with changes in climate, human impacts, and natural disturbances. Gradient studies, either altitude or latitude, are used to simulate climate variations. Of particular interest are studies involving ecotones and areas where species are at the limits of their natural range.

2. Controlled experimentation. In addition to field experiments involving complex ecosystems, controlled experiments using large open-top chambers and branch chambers under relatively natural conditions, and highly controlled greenhouse and small chamber experiments, are used to determine plant responses to altered physical environments, enhanced carbon dioxide, ozone and acid deposition, increased UV-B radiation, and increased insect stress. Interactions among stresses and responses involving photosynthesis, carbon allocation, and water balance within plants will be measured.
3. Soils. Soils contain nearly twice as much carbon as the atmosphere. Monitoring this major repository of carbon over time is needed to determine trends in soil carbon storage, and to develop an understanding of the processes which control the flux of carbon between soils, the atmosphere, and the biosphere. Emphasis will be placed on measuring soil changes due to acid deposition, weather/temperature changes, nutrient leaching, erosion, and natural and human-caused changes in vegetation, including those driven by a changing climate. Measurements will be made to evaluate global change impacts on soil properties that impair nutrient availability for plant growth. Equally important is global change influences on soil microbes, small soil animals, and methane production. The program will measure changes in the role that microbes and small soil animals play in breaking down large, complex organic molecules into smaller mineral nutrients which are then available for uptake by plants. Studies of the sensitivities of the mechanisms of nutrient cycling by microbes and small soil animals to global change will be given priority. Of special interest is the role and interactions of mycorrhizal fungi and other organisms in the rhizosphere with host and associated environments.
4. Model development and synthesis. Mechanistic models for individual species, functional groupings, and specific ecosystems are under development to describe processes of carbon sequestration and allocation, water balance, and nutrient cycles, and to predict changes in responses resulting from natural and human induced stresses along with prospective climate change. Biogeochemical models that couple climate to nutrient budgets, soil organisms, soil structure, function and productivity are being developed. These models are process oriented and driven by primary atmospheric and other environmental forcing. A major focus of this FSGCRP element will be the design of model shells that will facilitate interconnectedness and feedback loops between existing and new models at the variety of scales necessary to accomplish the twin objectives of predicting ecosystem responses to climate changes and climate responses to ecosystem changes. Models of insect, disease and fire disturbance effects on ecosystem structure, function and composition (being developed under the DISTUR element) will also be incorporated into the model shells. These model shells, and the process and disturbance component models that will be included within them, will constitute the primary terrestrial ecosystem representation for climate system and general circulation modelers under the US GCRP.

This FSGCRP Program Element is vital to

understanding and predicting the structure and composition of future ecosystems. Research which quantifies carbon storage in biomass, organic matter, the soils of forests and related ecosystems, and wood in use will be accelerated. Forests are a major repository of carbon taken from the atmosphere. Understanding the carbon cycle and its interrelationship with nutrient, water, and energy cycles is vital to determining the dynamics of the global carbon budget. This program is needed to understand and predict CO_2, CH_4, and sensible and latent heat fluxes as land use patterns change. Selecting land use and forest management strategies to maximize carbon storage one potential response to mitigate and adapt to global change, requires the detailed knowledge from this research.

MILESTONES------Atmosphere/biosphere Gas and Energy Exchange (ATBIOX):

1991-1995

Regional climate change scenarios. Outputs from contemporary coupled ocean/atmosphere general circulation models will be organized into global scenarios of possible future climates. Using regional and local climatological data to supplement the large-scale modeled climate, focused projections of the nature and magnitude of potential changes in space and time distributions of temperature, humidity, precipitation and wind that may be experienced by forest and related ecosystems in the US will be published. These scenarios of regional climate change will be used by the FS GCRP as well as other natural resource researchers.

Capability to generate local and regional climate futures. Since effects of climate change on ecosystems are highly interactive with microclimate and since both disturbance and management manipulate that microclimate, a capability to generate local climate scenarios must be provided to researchers. This capability may take the form of a computer software package, a centralized facility or some other mechanism as appropriate.

Design of a Terrestrial Ecosystem Model Shell. Researchers throughout the USGCRP will be developing models of components of terrestrial ecosystems. In order for these new generation models to be utilized to represent terrestrial ecosystems in global climate system modeling efforts, it is necessary to provide a framework or shell allowing component models to be coupled across time and space scales in a fully interactive manner. This shell will provide such a capability for all models supportive of terrestrial ecosystems.

Terrestrial Carbon budget accounting framework. In order to assess the role of the forest sector in global change, a model that incorporates the best data available (FIA) on carbon storage in US forests and projected carbon consequences of management and land use will be published.

Second generation terrestrial Carbon budget model. The procedures for modeling the carbon consequences of forest management, land use changes and climate change scenarios will be upgraded based on results of the FS GCRP, and incorporated into the FIA based Carbon accounting framework to provide a tool for use in assessing mitigation and adaptation alternatives.

Initial quantification of greenhouse gas exchanges with terrestrial ecosystems. Measurements of CO_2, CH_4, N_2O, H_2O, reactive hydrocarbons and aerosol exchanges between selected terrestrial ecosystems (boreal forests, temperate forests, semiarid woodlands, arid lands including riparian zones) based on eddy correlation and other technologies will be conducted and published. First generation models will be developed and published.

Preliminary assessment of Carbon allocation changes. Results of chamber studies will yield preliminary data on shifts of carbon allocation within significant plant species (Loblolly pine, Aspen, eastern White pine, northern red oak, Douglas fir, Ponderosa pine) and between associated ecosystem compartments.

1995-2000

Future local and regional climate scenarios. Climate scenarios that are specific to locations and ecosystems will be generated using second generation terrestrial ecosystem models operating within mesoscale atmospheric models which are nested within coupled ocean/atmosphere global circulation models.

Implementation and Application of a Terrestrial Ecosystem Model Shell. The Terrestrial ecosystem model shell will be constructed and applied to integrate detailed second generation terrestrial ecosystem model components into next generation climate systems models being provided from other programs of USGCRP.

Global terrestrial Carbon budget model. Procedures for modeling the terrestrial carbon budget applied previously in the US will be extended and coordinated with other agencies to provide a procedure that is the global standard for

terrestrial carbon budget.

Quantify greenhouse gas exchanges from managed and disturbed terrestrial ecosystems. Measurements of CO_2, CH_4, N_2O, H_2O, reactive hydrocarbons and aerosol exchanges between selected terrestrial ecosystems (boreal forests, temperate forests, semiarid woodlands, arid lands including riparian zones) as a function of management procedures (fire, grazing, thinning) and disturbance (fire, pest activity, storm damage) will be made.

Detailed assessment of Carbon allocation changes. Results of chamber studies and ecosystem level manipulations will yield data on shifts of carbon allocation within significant plant species (Loblolly pine, Aspen, eastern white pine, northern red oak, douglas fir, Ponderosa pine) and between associated ecosystem compartments.

Disturbance Ecology (DISTUR)

Disturbances are critical to the stability, health and productivity of ecosystems. Fire, insects and diseases, and weather-driven stress are disturbances that are critically dependent on both climate and the use and management of natural resources. Large scale disturbances in forests where people have significant presence are potential natural disasters. The Yellowstone fires of 1988, Hurricane Hugo in the coastal Southeast and the Gypsy Moth epidemic in the Northeast are examples. In the developing world the linkage to human survival is even more dramatic. Global climate projections suggest that the frequency and severity of drought, seasonality and spacial occurrence of precipitation, temperature extremes, strong winds and intense storms are all likely to change in the future. These climatic factors drive both the occurrence of and severity of fire, insect and disease episodes. The Forest Service program consists of three components:

1. Fire Wildfire and prescribed fire depend on the weather and the amount and structure of vegetation. With global change, vegetation (i.e., fuels) will change both directly in response to an altered climate and indirectly because of altered insect and disease activity. Fire is a major way that the ecosystem resets itself. Fires are also a source of trace gases as a result of combustion. This research will focus on the changed frequency and severity of fire weather, the processes in which the ecosystem transits from the current equilibrium between climate and ecosystems to a new equilibrium, and the production of trace gases and particulate matter which will contribute to the atmospheric composition.

Historical fire occurrence determined from fire scars on both live and dead trees will provide a record on fire frequency and severity over a long period of time. Coupling these data with dendroclimatological and pollen data gives a history of fire in transitional ecosystems and climate relations. Recent fire occurrence, weather, and land use activities will provide data from which anthropogenic fire can be separated from natural fire. Direct measurements of the emissions of a number of chemical species will be measured on wildfire and prescribed fire.

Understanding the role of fire in ecosystems, both human caused and natural fire, will provide information on how fire shapes the ecosystem and how the ecosystem recovers from major disturbances. Changes in land use patterns when fire is used to bring about change, and the resultant productivity of the land, will be investigated. Interactions between humans and fire (such as suppression activities, planned use of fire and, especially, the urban/wildland interface) are sensitive to climate and will be assessed.

Models to predict the emissions from fires will be developed which are based on weather, vegetation structure and amount, and on species composition. Smoke models will be developed to help manage deleterious effects from prescribed burning.

Fire is a major disturbance in ecosystem dynamics. Understanding how fire shapes the ecosystem to accelerate response to global change is of highest priority. Equally important is the need to quantify and predict the emissions of trace gases and particulate matter from fire and the contribution of these gases and particulates to atmospheric composition. The scientific merits of this program are very high in that it will contribute significantly to understanding disturbed ecosystems, and to quantifying the sources of trace gases and particulate matter from fire.

2. Insects and diseases There is a complex relationship between fire and insect and disease phenomena which combine to change ecosystems. Insect and disease epidemics may serve as early warnings of changes in ecosystems. Understanding how pests shape the ecosystem to accelerate response to global change and how global change will alter the patterns, intensity, and frequency of insect and disease outbreak is of highest priority. The scientific merits of this program are very high in that it will

contribute significantly to understanding disturbed ecosystems.

The research will focus on how global change influences the frequency and severity of insect and disease outbreaks. The importance of insect and disease outbreaks as a disturbance in the ecosystem and how those disturbances accelerate ecosystem change from one equilibrium to another will also be emphasized. Research will address the direct effects of global change on pest organisms as well as how insects and disease organisms function secondarily to influence stressed host species.

Monitoring of forest health and identification of insect and disease outbreak is an ongoing program. This activity would be supplemented through more intense monitoring to provide the database for mechanistic studies. There is also a need to identify changes in insect and disease outbreak severity that can serve as indicators of environmental changes.

Models of insect and disease disturbance on ecosystem structure and composition will be developed. In addition, interactions between humans and insects/diseases (such as suppression activities) are sensitive to climate and will be assessed.

3. Weather-driven stress Floods, high winds, and drought represent three examples of weather having the capacity to increase stress on ecosystems. In the semi-arid western US, the cycle of flood and drought dominates the landscape. Erosion and associated questions of sediment transport and channel maintenance are important management issues. Drought driven desertification is exacerbated by human use of the arid and semi-arid landscapes. Global change leading to an altered climate has the potential to either accelerate or retard desertification and land stability.

In coastal areas hurricanes and other strong winds are significant disturbance factors that serve a role in ecosystem succession. Increased frequency or intensity of these phenomena could exert a major force to shape the nature of the landscape.

Research to link ecosystem processes and weather-driven stressors will include studies of erosion, desertification, channel maintenance, sediment transport, floods and strong winds.

Research to analyze changes in fuel buildup and fire hazard due to global change and to predict wildland fire activity and emissions with global change has been initiated. Methods to model changes in fire severity and occurrence based on General Circulation Model (GCM) outputs are being developed. Direct measurements of emissions from wildfires and prescribed fires will be made to validate the models. Predicting fire hazard will allow adaptive measures to be implemented in fighting forest fires. Because of the accelerated accumulation of CO_2 and other gases in the atmosphere, predictive models that quantify emissions from forest fires are of high priority. Pilot studies for forest health monitoring will determine the best ways to measure the current insect and disease conditions of forests in two Western States. Models predicting the growth and yield of forest trees will incorporate important insect and disease considerations.

MILESTONES-----Disturbance Ecology (DISTRUR)

1991-1995

National assessment, at a State level of resolution, of potential changes in the fire load as a result of the climate change scenarios identified above in ATBIOX outputs.

National assessment, at a State level of resolution, of potential changes in other disturbances and their interrelationships as a result of climate change and pollution. This will include development of a climate sensitive National Forest Pest Danger Rating System.

Global inventory of primary emissions from biomass burning. This will include a model for the output of forest fire smoke under various GC projections.

Define the structure of a general disturbance ecology model, or modelling framework.

Risk assessments of fire disturbance, pollution driven disturbances and other climate driven disturbances. Initial issued in Fy 93 and periodically thereafter.

1995-2000

Improved assessment based on better understanding/specific studies of climate vs. fire severity.

Preliminary development of a disturbance model that will include some of the major disturbances (wind, fire, insects, etc.). The model will also be a component of the assessments delivered in ECODYN.

Ecological System Dynamics (ECODYN)

The response of forest and rangeland ecosystems

to global change will be the focus of this research. Dynamics of ecosystem nutrient and hydrologic cycles as well as vegetation cover will be determined. Study of ecotones will be emphasized, where sensitivity is greatest and change is most likely to occur. Ecosystems at risk, particularly wetland ecosystems, will be intensively studied.

The objective of this research is to understand and anticipate the alterations that will result from environmental change, and to understand the sensitivity of key ecosystem processes and ecosystem components to environmental gradients. Coupling mechanisms between the atmosphere, vegetation, land surface, and the hydrologic cycle will be studied. Threshold limits of ecosystem stability and diversity will be determined. Life histories, population dynamics, competitive interactions, and community dynamics of plants under altered environments will be addressed. Attention will be given to threatened, endangered, and sensitive species.

Environmental factors threatening ecosystem function vary greatly depending on location. Research will be directed at (1) determination of plant and animal species composition and the critical characteristics that ensure viable function of each component in the whole system; (2) evaluation of water quality and quantity and the impact of changes in these characteristics that affect biological diversity, and the role of forests and rangeland in protecting water quantity and quality; and (3) assessment of environmental impacts directly on vegetation or indirectly on the chemistry of soil or water quality which may result in increased degradation of soils thereby impacting ecosystem dynamics.

Long-term investigations of watershed and ecosystem processes in experimental forests and watersheds will be an important part of this approach. Observations along environmental gradients and across ecotones will be added. Paleoecology will be used as a historical base of forest health and productivity. Controlled experiments will provide data on genetic resilience to stress and adaptability to changing environments. Ecosystem models and production models will be developed and applied.

MILESTONES------Ecological system dynamics (ECODYN):

1991-1995

Develop maps which depict historical patterns of forest vegetation distribution under changing climate conditions.

Develop a modeling shell which will be used to predict the effects of changing climate conditions on forest vegetation growth, reproduction, and distribution.

Develop a modeling shell to predict the effects of changing climate conditions on ecosystems (distribution, structure, function and productivity) utilizing latest generation component models. This will contribute to FS-ATBIOX system model for large scale climate predictions

Identify those forest ecosystems where sustainability appears to be threatened as a result of global change.

Integrating Human Activities and Natural Resource Changes (HUMANI)

The objective is to determine how global change will impact human activities and how human activities, through agriculture and resource management, will affect global change. Currently, strategic planning for natural resource management is based on econometric models of land use and resource supply and demand through the planning and assessment process mandated by the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA). These models integrate the physical and biological world with that of the social and economic structure of society. A fully integrated resource planning model will need to incorporate both the changes of the physical and biological environment (addressed in other Forest Service Global Change Programs), interactions of humans with the environment, and the social/economic changes that will result from global change.

Current models used by USDA to assess resource interactions with society are loosely integrated with global change models. The human component of natural resource models needs to include feedback mechanisms between social systems, global change, and natural resources. This can be accomplished by developing modules which bring global change and human influences into assessment models in a fully integrated and interactive mode. Strategic planning, based on assessment of future resource supply and demand, risk assessment, and risk management in a changing environment, will require research on the processes and interactions of humans, global environment and resources. Models must be developed to account for these processes in strategic planning.

The Human Activities and Natural Resources Program will conduct research in three broad

problem areas:

Identification and assessment of the effects of forest ecosystem responses to climate change on communities and society.

Identification and evaluation of policy options in rural and urban forestry for mitigating and adapting to the effects of global change.

Integration of risks associated with prospective climate changes into rural and urban forest management decision processes.

Implementation of these activities will require development of new models that are closely linked to the models currently used to assess the forestry sector. Current econometric models used by the Forest Service in policy analysis include a land use model, a timber market model, a forest inventory model, and models of nontimber forest resource interactions. These models collectively describe the forest sector, and will be enhanced to include interactive responses to prospective climate changes, in particular, to observed and predicted changes in forest composition, health, and productivity. Forest sector models involve all the aggregated forest lands of the U.S. rather than any particular forest ecosystem.

The Forest Service uses a variety of national and regional models for land management planning. Research underway in ecological systems and dynamics will provide the basis for modifying empirical relationships in planning models so that the effects of climate change on resource productivity can be incorporated into the decision making process. Also needed under global change are evaluations of changing landowner objectives and associated effects on management decisions, and better methods for valuing non-market resource outputs.

The Forest Service has been involved in major assessments of current and prospective forest resources for over 50 years, and has a major influence on land management decisions through National Forest planning, State and Private Forestry activities, and Research. There is a basic modeling structure and expertise in place that can answer many policy and management questions affecting future forest resources and interactions with society. Research is already underway to improve the capability of forest sector models and management decision models to assess options under a changing environment. The Forest Service has a commitment to conduct related research under the global change program that will provide much of the data needed by USDA resource economics and assessment programs.

MILESTONES------Integrating human activity and natural resource changes (HUMANI):

1991-1995

Forest sector model linked with carbon budget model. Econometric models of forest resource interactions with society are enhanced for (1) analysis of national and regional changes in commodity and non-commodity resource outputs and values, and (2) evaluation of alternative policies for mitigating or adapting to global change. Capability developed for evaluating alternative climate change scenarios.

Climate-interactive land use projection model developed. An econometric model of land use changes that would result from climate change scenarios would be integrated with the forest sector model and used to evaluate land use and vegetation interactions.

Integration of global change into forest management planning. Forest land managers and urban foresters have the option of evaluating management objectives and decisions based on risk assessments of disturbance effects, and possible changes in ecosystem dynamics associated with global change. Accomplished through evolution of forest management planning models.

Identification of communities and social groups at risk. How might changing urban and rural forest conditions affect the viability of communities and lifestyles of individuals? Evaluation based on sociological case studies of analog situations.

Identification of historical relationships among climate change, ecosystem conditions, and society. Archaeological and historical records analyzed for selected societies to uncover basic relationships that can be used in predictive models.

1996-2000

Improved resolution of integrated forest sector and carbon budget models. Econometric models are capable of evaluating effects of climate change on local economies, and evaluating the cumulative effects of local management decisions on gas exchanges with the atmosphere.

Projections of land use overlaid on potential vegetation. Projections of changes in land use as a consequence of climate change are used to map expected effects on vegetation. The altered vegetation is compared with projections of changes in the distribution of forest ecosystems.

Continued integration of global change into

forest management planning. Continued evolution of forest management planning models to incorporate the effects of global change into the planning process.

Inventory of communities and social groups at risk. Based on earlier evaluation, conduct an assessment and inventory of those communities and social groups for which the risks associated with prospective climate changes are highest.

Analysis of prospective societal changes in response to climate change. Using basic relationships developed earlier, climate change scenarios, and prospective ecosystem responses, analyze how society might respond to widespread, significant changes in climate.

Status of Global Change Program: National Forest Service System

Rhey Solomon

Introduction

The Forest Service is divided into five branches, each of which has its own policies and programs relative to the overall mission of the Forest Service. These five branches are: (1) Research, (2) The National Forest System (National Forests), (3) State and Private Forestry, and (4) International Forestry and (5) Programs and Legislation.

Research. The Forest Service Research program is focused primarily on researching forest and range ecosystems, products produced from forests and rangelands, and the economic and social benefits and costs associated with managing forests. The Research program is well established within the Forest Service dating to 1905.

National Forest System. The National Forest System consists of the 157 National Forests throughout the United States. This program is responsible for the management of over 191 million acres within the system. This is the largest branch of the Forest Service with the largest budget and greatest number of employees.

State and Private Forestry. The State and Private program is structured around providing technology transfer to States and private landowners on all aspects of forest management and forest products. Cooperation in wildfire suppression, insect and disease control, and other forest related problems that cross administrative boundaries are the function of State and Private Forestry.

International Forestry. International Forestry provides the link to foreign countries by providing cooperative research and technology transfer on forest management. This program has existed since the 1930s but was elevated in 1991 to a status equivalent to the other three major program areas.

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Policy and Existing Programs - Programs and Legislation

The policy of the Forest Service relative to climate change is outlined in the Resources Planning Act (RPA) Assessment and the RPA Program. The Assessment document states:

There is great uncertainty in the projections of climate change on local ecosystem responses. However, we can say that these factors will play a major role in abrupt changes in the landscape: changes in precipitation and, to a lesser extent, temperature will restrict the persistence of ecological systems; and changes in disturbances, such as fire, insects, and disease, will impose new and different stresses on ecosystems (Joyce et. al 1990).

This statement recognizes that climate change is a possibility and that climate change would result in changes to fire, insects, disease, and ecosystem communities.

The RPA goes on to suggest three possible strategies, (1) conservation of forest resources, (2) mitigate the effects of climate change, (3) adapt to climate change (Joyce et al. 1990). These strategies are identical to the strategies identified by a study on policy implications of climate change undertaken by the Committee on Science, Engineering, and Public Policy (CSEPP 1991).

The RPA Assessment goes on with the following:

The third option, that of adaptation, offers the greatest flexibility in managing forests in a changing climate. Adaptive strategies involve developing new technologies to utilize the resources of the future forests. Because of the uncertainties in the current prediction of impact of climate change on America's forests, we will need to continue careful monitoring and surveillance of our forest ecosystems, particularly those components which are highly sensitive to the greenhouse effect in order to refine management strategies. Also, because our current capability to predict impacts is imprecise, we must continue to carry out research on the effects of multiple

stresses on our forests in order to assure their health and productivity in a changing atmospheric environment (Joyce et al. 1990).

The RPA Program identifies "Global Stewardship" as a contemporary issue that will challenge the agency as a long-term issue with national implications. The Program specifically states some agency responses (USDA Forest Service 1990a).

1. The Forest Service will expand research to more fully understand the effects of global climate change on forests, rangelands and related ecosystems.
2. The Forest Service will take a leadership role in developing limitation and mitigation technologies for forests and rangelands.
3. As part of the President's "America the Beautiful" initiative, the Forest Service will expand its tree-planting program through the State Foresters on nonindustrial private forest lands and in communities to help mitigate temperature changes that affect Earth.

The essence of these statements is that the position of the agency is to conduct research on climate change effects to forest ecosystems and evaluate adaptive strategies. The agency will not take directed action, at this time, on any of the three principal strategies until definitive answers on the extent, intensity, and effects of climate change on forests are better known.

Research

Programs within the Research branch of the Forest Service are addressed elsewhere (USDA Forest Service 1990b).

National Forest System

The Forest Service has focused on the need for climate change research before making land management decisions directed at, or in response to, climate change. Regardless, the agency is being asked to address climate change as part of planning and NEPA disclosure. In response, the agency has begun to formulate a position relative to addressing climate change as part of environmental analyses. Table 1 summarizes this position.

Project Level/Forest Level. Decisions at the Forest (Forest Plan) or project level involving vegetation management have insignificant impacts on global climate change and, therefore, estimating the small incremental contributions of greenhouse gases at that level is not meaningful to a reasoned choice among alternatives. It is possible to make estimates of carbon balance for projects or the Forest plan. However, such estimates cannot be translated into incremental contributions to climate change. Therefore, such estimates only serve to quantify other environmental interpretations such as loss to soil productivity, local impacts to air quality, etc. The above information can be used to briefly discuss this issue and for the reasons discussed above, dismissed from detailed analysis. When Regional estimates of climate change (i.e., temperature, precipitation, extreme events) are improved over the next decade, it will be appropriate to consider global change scenarios as a reasonably foreseeable future when looking at long term planning of over 50 years, such as forest plans. This will require considering the long term decisions and their adaptability or compatibility with possible climate change.

Regional Level. It is currently not possible to estimate with any degree of reliability the contribution of Regional programs to climate change. Two major reasons account for this; (1) in general, the increment of greenhouse gases from Forest Service activities when compared to other regional sources of these gases is far less; and (2) the state-of-the-art does not allow for correlation of regional sources of greenhouse gases with changes in General Circulation Models. However, it may be necessary to estimate the relative contribution of greenhouse gases of Regional programs as compared to other Regional sources. This will put the issue in perspective and demonstrate if indeed the Regional program is an important contributor to greenhouse gases. Additionally, as more information becomes available on climate change, it will be necessary to consider these changes as a reasonable foreseeable scenario to ensure that long term management decisions take this factor into account.

National Planning and Programs. At this time, the RPA Assessment and Program are the appropriate level at which program impacts to climate change and adaptive mitigative strategies can be addressed most effectively and coordinated with other agency programs.

Table 1. Position for Addressing Climate Change in Environmental Analyses.

Planning Level	Estimate Greenhouse Gases	Estimate Effects on Climate Change	Adaptive or Mitigative Strategies
RPA, National Programs	YES	YES	YES
Regional Programs (Multi-Forest State)	YES - to put in perspective with other Regional sources.	NO	When info on Regional climate change are available
Forest Plans (1 to 3 million acres)	NO - but only if for other environmental effects analysis needs.	NO	When info on Regional climate change are available
Projects	NO - but only if for other environmental effects anaysis needs.	NO	NO

State and Private Forestry

Within the State and Private branch of the Forest Service is a program titled "America The Beautiful". The President proposed this environmental initiative which will enhance existing natural and recreational resources, and will address mounting concerns about the buildup of atmospheric carbon dioxide. It includes a major nationwide tree planting program and a substantial expansion of land acquisition. The goal of this effort is to plant, improve, and maintain nearly one billion trees. This effort has been viewed by some as a climate change mitigation effort, in part.

International Forestry

There is no definitive policy or program under International Forestry that specifically addresses climate change. The Forest Service is working through the State Department and with other agencies in formulating a position of the United States as part of the Global Forestry Agreement. This agreement addresses the rate of deforestation of tropical forests. Additionally, the Forest Service is working intently with countries of South America to reduce the elimination of tropical forests. The agency is providing technical expertise on forest management and approaches for how to use these forests to produce goods and services.

Agency Expertise

The expertise within the agency to address changes and adaption to climate change reside primarily within the Research branch as discussed elsewhere.

Data Bases

Data bases on climate change are being coordinated through the Research branch of the Forest Service as discussed elsewhere. However, as part of the management of the National Forests, weather stations have been set up to collect data needed for management of the National Forests. These stations are primarily for fire management purposes. The network consists of 900 manual fire weather stations and more than 300 remote automated weather stations (RAWS) to assist in the monitoring and control of wild fires as well as prescribed burning and other resource management decision making (Tucker 1991). The RAWS data are stored by the Western Regional Climate Center at the Desert Research Institute, Reno, Nevada. This RAWS system is coordinated between the BLM and the Forest Service. Hourly RAWS data are stored.

This weather information is being collected at remote sites that can provide a valuable source of climate information. However, this data is

currently not being collected for purposes of climate change. Quality control standards, climatic parameters, and frequency of measurement could be modified to make this data useable for climate change data. The Forest Service has no plans to modify RAWS protocols unless a multi-agency coordinated effort is undertaken to design a nationwide climate change network. specify data protocols and parameters, and centrally manage the data.

Funding Base

There are no funds specifically programmed for climate change except for those within the Research budget as discussed elsewhere.

Accomplishments

Accomplishments in the area of climate change are limited primarily to research efforts. However, there are a number of accomplishments in the other program areas that, although not directly related to climate change, do have implications.

National Forest System

As part of Forest planning, ecosystem mapping is mostly complete for the entire National Forest System. The data will serve as a benchmark for mapping changes in ecosystems that may result from climate change. These data are currently being incorporated into GIS data bases for the next round of Forest planning which is just now getting underway for some forests in the Alaska and the Rocky Mountain Region (Colorado, Wyoming, South Dakota).

Also, the agency has filled claim to instream flow needs in a number of Western States as part of state water rights adjudications. These claims are made for the quantities of water necessary to support natural hydrologic and ecologic processes associated with stream systems. If climate change does affect precipitation and water runoff, these water rights could serve as the basis for maintaining instream water needs associated with managing the National Forests.

State and Private Forestry

"America the Beautiful" is the single most visible program within the State and Private area that has been linked to climate change. This program began in November of 1991 with a goal of planting 970 million trees in rural areas and 30 million trees in communities.

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Status of Global Change Program: Agricultural Research Service

Wilbert H. Blackburn

Recent evidence continues to support the premise that global climate change is one of the most important environmental issues of the 21st century. Increased concentration of carbon dioxide and other trace gasses created by human activities is assumed responsible for the greenhouse effect that could potentially warm the Earth's environment.

Any warming of the Earth's environment will affect the Nations croplands, rangelands and forests that are basic to our national security and a strong national economy. These managed ecosystems are the base for sustaining global environmental quality, productivity, health, and diversity. Agriculture will face major challenges if predicted climate changes prove to be accurate. Temperature increases could alter precipitation regimes and increase plant transpiration, thus altering water supplies, decreasing streamflows and reducing soil water content. The resulting costly and erratic food supplies and depleted natural resources could adversely strain our national economy.

Policy

The mission of ARS is to develop new knowledge and technology needed to solve technical and agricultural problems of broad scope and high national priority in order to ensure adequate production of high-quality food and agricultural products to meet the nutritional needs of the American consumer, to sustain a viable food and agricultural economy, and to maintain a quality environment and natural resource base. As the in-house research arm of the USDA, ARS has primary responsibility to: 1) provide initiative and leadership in agricultural research; 2) conduct research on broad regional and national agricultural and related problems, 3) conduct research in support of Federal action and regulatory agencies, 4) provide technical expertise to meet national food, safety, and environmental emergencies, 5) serve as an agricultural science resource to executive and legislative branches. Cooperative research by ARS and state and industrial scientists is encouraged as an efficient means for increasing the overall benefits that accrue from public investments in agricultural research.

ARS provides the ability to perform long-term, high-risk research, respond to stable and changing technical goals, focus research on gaps in knowledge that are barriers to problem solution, and an organizational structure ensuring research program accountability and coordination, capability to form, disban, or coordinate interdisciplinary or multi-location research teams from a large, diverse scientific work force of over 2,600 research scientists.

ARS global change research program is part of USDA's contribution to the United States Global Change Research Program (USGCRP) coordinated by the Global Change Working Group of the Federal Coordinating Council for Science, Engineering and Technology's Committee on Earth and Environmental Sciences. The program goal is to develop a model of the Earth as an integrated system comprising land, ocean, and atmosphere. Preliminary models have been developed for the ocean and the atmosphere but not for land. The objective of the ARS program is to develop a comprehensive model for the land-based biosphere component of the Earth system as a means of understanding how both natural and human-induced processes will affect future environmental changes, as well as to provide the basis for designing response strategies that secure the continued productivity and health of the human life-support system.

Existing Program

ARS' existing program in global change encompasses both applied and basic research and is a mix of modeling and experimental methods that build on the synergism of both methods. ARS program is divided into three major areas supporting high-priority science elements of the USGCRP: 1) climate and hydrologic systems, (2) biogeochemical dynamics, and 3) ecological systems and dynamics. ARS Climate and

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Hydrologic Systems program "Global Change, Water Resources and Agriculture (ARS-GCWRA)" objective is to improve the ability to predict water and energy fluxes within and from managed ecosystems, by developing methods for describing the spatial and temporal characteristics of water and energy fluxes at various scales. Results from this program will affect policy responses to a wide range of environmental and economic issues such as atmospheric warming, water supplies, and food security. The ARS-GCWRA program is closely related to and draws on ARS global change programs in Biogeochemical Dynamics and Ecological Systems and Dynamics and on the ARS base programs in water quantity. For more information on related water quantity programs in ARS see Donn G. DeCoursey's status report "ARS Position Paper on Water Quantity and Water Quality" (this workshop).

Research Resources

Expertise

Expertise of the scientific staff working in the ARS-GCWRA program represents agricultural, environmental and hydraulic engineering, hydrology, mathematics, meteorology, physics, biology, range and soil science.

Facilities

ARS is currently collecting data at 140 watersheds representing 17 different resource areas in 12 states. Of the 14 research centers of ARS which are currently conducting hydrologic research, 11 centers have on-going data collection programs. Several of these locations have been collecting continuous, variable time-series data for basic parameters such as rainfall, runoff, temperature, and sedimentation for over 50 years. The length of record for the 140 experimental watersheds range from less than 10 years to more than 30 years. Fifty watershed have records for more than 20 years. The Reynold's Creek Experimental Watershed (233 km^2) located 80 km southwest of Boise, Idaho; the Walnut Gulch Experimental Watershed (150 km^2) in southeastern Arizona; the Little Washita (637 km^2) located in central Oklahoma; and the Blacklands Experimental Watershed (25 km^2) near Riesel, Texas along with the other experimental watersheds, their long-term data sets and their associated research facilities comprise vital resources for global climate change research. ARS experimental watersheds have proven to be a valuable resource in the development of large-scale strategies for collecting parameters necessary to support physically-based models used in climate change studies. The development and validation of techniques such as remotely-sensed data and GIS representations have been developed for several of the ARS experimental watersheds.

Data Bases

In addition to data bases at each watershed location, ARS operates the Water Data Center (WDC) that is responsible for organizing and disseminating water data collected by the agency. WDC makes the data available to the research community through direct request and through an on-line computer system, REPHLEX II. Over 13,000 station years of data are stored in the Water Data Base. This includes approximately 8,400 station years of precipitation and 5,000 station years of runoff data. These data represent information from 333 different study areas varying in size from 0.2 ha to 536 km^2. Plans are being developed for the WDC to manage the storage and distribution of data files needed for the ARS-GCWRA program which include the indexing and possibly the storage of GIS files, elevation data, and remotely-sensed parameters for the experimental watersheds included in the ARS-GCWRA program.

Funding

The ARS climate and hydrology program (ARS-GCWRA) is relatively new to ARS and is currently funded through an internal redirection of base funds at six locations having the required expertise, facilities and interest in the ARS-GCWRA initiative that is currently being considered by Congress for funding. The six locations are: Northwest Watershed Research Center, Boise, ID; Southwest Watershed Research Center, Tucson, AZ; Hydrology Laboratory, Beltsville, MD; Water Quality and Watershed Research Laboratory, Durant, OK; Grassland, Soil and Water Research Laboratory, Temple, TX; and the Hydro-Ecosystem Research Unit, Ft. Collins, Co. Funds currently being used at ARS locations identified in the 1992 global change initiative (ARS-GCWRA) are approximately $2 million. If the house budget for ARS-GCWRA is approved an additional $2 million will be added to the program. ARS funds expended on the two allied Global Change

Programs, Biogeochemical Dynamics and Ecological Systems and Dynamics is $4.6 million. Related water quantity research programs are funded at $45.8 million (for additional information on funding of related water quantity programs see Donn G. DeCoursey's report "Status of Water Quantity and Quality Program: Agricultural Research Service").

Accomplishments

Research on global climate change and its effects on water resources received little attention in ARS prior to 1989. Consequently, accomplishments related to global climate change and hydrology have evolved at the six research locations from the work of individual scientists not from an integrated ARS program. Some recent accomplishments relating to ARS-GCWRA initiative are briefly summarized.

1. **Quantification of precipitation change** - Techniques have been developed to quantitatively identify the effects of the Southern Oscillation Index (SOI) on the parameters of a stochastic daily precipitation model. The effects of SOI and possible deterministic trends introduced by lunar and solar cycles must be accounted for before it will be possible to detect precipitation changes due to the greenhouse effect.
2. **An interdisciplinary field study of water and energy fluxes in the atmosphere-biosphere system over semiarid rangelands** - Two major field campaigns (1990-1991) have been completed over the Walnut Gulch Experimental Watershed in Arizona. The emphasis of the project was on the collection and analysis of hydrologic, meteorologic data during the southwest monsoon season when the region receives a majority of its annual precipitation. The results of this study will improve our understanding of water and energy fluxes over large semiarid areas and how best to monitor and model the effects of climate change on the regions water resources using information from remote sensing satellites.
3. **Rainfall-runoff dynamics over a range of watershed scales** - Detailed analyses of runoff dynamics on four sub-watersheds of Walnut Gulch have been completed. The findings from this study have important implications to the aggregation of runoff responses from small watersheds to the subgrid General Circulation Models because they are not compatible with numerous earlier reports indicating an increase in the linearity of the runoff-area relationship with increasing watershed scale.
4. **Spatial and temporal response of precipitation-streamflow dynamics over a range of scales** - Detailed data collected at the Reynolds Creek Experimental Watershed in Idaho on the spatial and temporal response of snow accumulation and melt on streamflow dynamics over a range of scales is being analyzed and modeled. The results from this study have important implications with respect to water and energy flux variabilities at various scales in mountainous terrain.
5. **Spatial and temporal response of soil water and soil frost at various scales** - the stochastic description of soil water is currently being investigated at the Reynolds Creek Experimental watershed. Although, the study is in its early stages, it is providing important information to improve the predictably of water and energy fluxes at large landscape scales.
6. **Relationships among soil water, temperature and vegetative growth** - Fundamental relationships among precipitation, soil water and temperature, and vegetative growth are currently being investigated using field experimentation and numerical modeling at the Walnut Gulch and Reynolds Creek Experimental Watersheds. The results from these studies will be used to test and validate regional hydrologic models that incorporate surface-atmospheric interactions in simulations designed to evaluate the effects of global climate change on the water balance in semiarid regions.
7. **Water supply implications of global climate change** - Scientists at the Hydrology Laboratory in Beltsville, MD are using the SRM (Snowmelt Runoff Model) and scientists at the Northwest Watershed Research Center in Boise, ID are using the NWSRFS (National Weather Service River Forecast System) to investigate the effects of climate change on the snowpack and streamflow of mountain watersheds in western North America. The model results indicated a potential serious problem in western North America where climate change could widen the gap between water supply and water demand and reduce the

effectiveness of existing water storage and distribution systems.

8. **Spatial and temporal distribution of evapotranspiration from rangeland plant communities** -Scientists at the northwest Watershed Research Center in Boise, Idaho, are using the Bowen ratio method to determine evapotranspiration rates from range landscapes.
9. **Simulation of climate and weather variable** - Scientists at several ARS locations (Boise, Durant, Temple, and Tucson) have developed models for generating synthetic sequences of weather data. The parameters of these models have been determined for all parts of the United States. The models can be used with hydrologic process models to project the hydrologic consequences of specific climate senarios.
10. **Global climate change and erosion on semiarid rangelands** - Scientists at the Southwest Watershed Research Center in Tucson, AZ and University of Arizona are using the Water Erosion Prediction Project model to investigate the effect of global climate change on vegetation and associated effects on upland surface runoff and erosion.
11. **Effects of global change on precipitation occurrence, amount, and intensity distributions** - Changes in atmospheric composition are expected to change precipitation regimes. Rainstorm characterization research in Temple, Tucson and Ft. Collins, has produced resuts which are directly applicalbe to global change problems.

Future Direction

Future ARS research on climate change and hydrology from the present time into the 21st century will be guided by the program documented in "Agricultural Research Service Global Change, Water Resources and Agriculture (ARS-GCWRA)". This program has two initial elements specifically targeted to meet the needs of the U.S. Global Change Research Program: Program Element I - predict water and energy fluxes to, within and from managed ecosystems; and Program Element II - evaluate scale effects of hydrologic processes. Both of these elements fall within the climate and hydrologic systems science element of the U.S. Global Change Research Program developed by the Federal Coordinating Council on Science, Engineering and Technology and it's Committee on Earth and Environmental Sciences (CEES). ARS-GCWRA also addresses the National Academy of Science, scientific priorities and data requirements that are listed in their 1991 publication on "Opportunities in the Hydrologic Sciences." A number of research programs proposed by other Federal Agencies have been identified as having components or features that are directly applicable to the ARS-GCWRA research program. Consequently, ARS will promote cooperative and supportive interactions with the related global change programs of other agencies under CEES. Likewise, ARS-GCWRA supports the Terrestrial Ecosystem Regional Research and Analysis Interagency Laboratory (TERRA Lab) proposal initiated by USDA and USGS. The research to be conducted within the two major program elements of the ARS program is described below.

Fluxes of water and energy to soil water, groundwater and streamflow

1. Model components will be developed to improve estimates of water available in the soil, ground and surface components of watersheds up to 10,000 km^2 as affected by temporal and spatial variability. This research effort will accelerate the development of models that can directly incorporate advances in remote sensing and geographical information systems technologies.

Fluxes of water and energy to and from the atmosphere

1. Model components will be developed to improve estimates of water and energy fluxes between the land surface and the atmosphere at elemental scales up to 10,000 km^2 as affected by temporal and spatial variability. This research effort will eventually provide new water resource models that are fully compatible with remote sensing and geographical information system technologies.
2. The best available technology will be used to determine the effects of potential climate change on water and energy fluxes to, within and from managed ecosystems for all climatic conditions including droughts at elemental scales up to 10,000 km^2
3. Knowledge gained in the development and

application of model components will be used to develop scenarios for mitigating global climate change effects on agriculture systems negatively affected by change and enhancing the effects on those systems positively affected by change.

Data base development needs for historical and current experimental watersheds, including remotely sensed information and ground based data relevant to ARS-GCWRA are:

1. Compile long term data sets from existing data bases, and make them available to global change investigators.
2. Develop archival data sets for large area hydrology experiments that are made available by the Water Data Center through an on line distribution system to investigators.

Cross Cutting Topic Areas Related to Global Chance Issue

1. Improve estimates of water available in the soil, ground and surface components of watersheds up to 10,000 km^2 as affected by temporal and spatial variability.
2. Improve estimates of water and energy fluxes between the land surface and the atmosphere at elemental scales up to 10,000 km^2 as affected by temporal and spatial variability.
3. Data base development for historical and current experimental watersheds and SNOTEL sites, including remotely sensed information and ground based data relevant to the global change issue.
4. Develop collaborative projects to assess the interactive effects of changes in the climate and land management systems systems on the components of the hydrologic cycle, drought, and flood frequencies and severity.
5. Develop collaborative projects to determine the effects of different land uses, forest, pasture, range, irrigated and rainfed crops on water and energy fluxes under a range of climatic conditions.
6. Determine the effects of potential climate change on fluxes of water and energy to, withing and from managed ecosystems for all climatic conditions including droughts at elemental scales up to 10,000 km^2.

Status of Global Change Program: Soil Conservation Service

Richard Arnold

Policy

There was very little activity by the agency on the global change issue in FY88 due to the huge workload related to Farm Bill. In FY88 funds for all of the Soil Survey and part of the Resource Inventory programs were shown as contributing funds to the global change issue. This was corrected in FY89. In FY89 the Soil Survey was permitted to have a $1.5M global change initiative with the caveat that likely it would be funded with redirected funds and that turned out to be the case. The interest level on the global change issue is still relatively low, however, there is more awareness of the need to be involved because of the relevancy of our soil databases and resource inventory information (NRI) to this issue. New initiatives are now acceptable and are expected to continue.

Existing Program

1. Pedosphere climate data collection.

In FY91 we instrumented 11 sites and updated 2 sites using meteor-burst technology of the SNOTEL system. These stations collect soil moisture and temperature at 6 depths, air temperature, solar radiation, wind velocity, and precipitation. The system can transmit 62 kinds of information if appropriate sensors are installed.

2. Soil Taxonomy classification of soil climates.

Currently we use 6 moisture regimes: aridic, ustic, xeric, udic, perudic, and aquic. We use 5 main temperature regimes and have iso-equivalents where summer and winter temperatures differ less than 5 °C. We are testing cool and warm phases and megathermic regimes.

All soils have temperature and moisture regimes but few have been measured. Therefore, we make estimates of the regimes using the Newhall model as modified for PCs. Using the long term records for the US and now for the world we have produced preliminary maps showing the distribution of stations and our estimates of pedosphere climates. Several climatic stress indices are also being tested.

Agency Expertise

Soil surveys and associated databases for traditional reports are of long standing. A hierarchy of maps is being worked on: SSURGO, STATSGO, NATSGO --county to national level. Soil classification and progress toward development of a international classification system is unparalleled. The National Soil Survey Laboratory, Lincoln, has an international reputation for their work on soil characterization.

National resource inventories have been conducted since the late 1940s with a systematic sampling for the RCA over the past decade. The results aid in guiding USDA's soil conservation activities. Data provided by the SNOTEL system is widely used in forecasting water supply in the western states.

Data Bases

NRI provides state and the state portion of MLRA's reliable information about the status and trend of natural resources at 5 and 10 year intervals.

SNOTEL sites provide databases that deal with the snow pack, water content and distribution. A climate facility will handle the newly acquired soil climate data from these remote sites.

The National Soils Information System (NASIS) will include the major soil databases such as the map unit use file, soil interpretation records, laboratory characterization data, official soil series descriptions, pedon descriptions, classification records, a guide to state laboratory data, and several others. Digital map data is being compiled and archived by the National Cartographic Center in Ft. Worth. Soil fertility test data is not in our data bases as they are handled by individual states.

Author is Director of the Soil Survey, SCS, Washington, D.C. 20013

Funding Base

First year of funding was FY91 with 1.5M and supplemented with 0.3M.

Anticipated Funding	93	94	95	96
Automated data	3.7	2.7	2.8	2.9
Aerial gamma	.5	.5	.5	.5
Soil Models/Climates	2.3	3.3	3.2	3.1
	6.5	6.5	6.5	6.5

Accomplishments

We are becoming players and cooperators with respect to the global change issue. On an international scale we are assisting with soil classification which include climatic parameters. An initial effort for developing a network of soil climate stations is underway; incorporating from 10 to 100 new sites a year. We are hoping to instrument 2000 sites if funding permits. The development of soil genesis models that unify our knowledge is also underway. We expect to be able to help refine soil carbon estimates. We will assist Long Term Ecological Research sites (LTERs) with site and soil characterization. We will co-host a permafrost soil workshop in 1993.

Important Water Resource Issues Related to Global Change

1. Quantifying the effects of land use and management, including agriculture and forestry on soil carbon.

   The Office of Management and Budget is interested in USDA information about this issue as it relates to budget allocations in the near future. This is an opportunity to bring together our expertise and present objective information, both as to present knowledge and to suggest research needs.
2. Determination of pedoshere climates and where they occur.

   Soil taxonomy utilizes soil moisture and soil temperature regimes that provide an additional method of looking at agroecological zones. This helps relate atmospheric climate to soils and is a useful tool in extrapolating our research results.
3. Determination of the reliability and probability of occurrence of a particular soil climate at a location or for a small area.

   Often our generalizations mask the variability that is relevant to developing strategies for mitigating the effects of climate change. Refinements of our estimates could prove to be valuable in suggesting modifications of agricultural and forestry practices.
4. Providing near real time ground truth data on pedosphere climate linked with atmospheric climate for different user groups.

   There appear to be needs to calibrate, validate, test and refine models with measured data. Relating to AVHRR is another aspect of application. We are in the planning phase to determine the size of the network and where sites should be located to maximize usefulness for US scientists.
5. Extrapolating Soil Taxonomy world wide.

   An effort is underway to redo the FAO world soil map into Soil Taxonomy terms so that soil climatic patterns can be visualized and used in searching for regions of similarity. A relatively small attribute file will also be prepared.
6. Cataloging qualitative landscape models.

   Pedologists build their pedosphere universe through qualitative models of (a) soil property patterns in landscapes and (b) hydrologic patterns in landscapes. Soil genesis models deal with material and profile development as a sequential set of events (history of segments of the earth) and also as dynamic soil processes interacting to develop diagnostic properties and horizons (more temporal). Of special interest are the

concepts of recharge, flow through, and discharge areas of landscapes as viewed by pedologists.

7. Soil database development. NASIS - the national soil information system.

   The whole data base structure is being analyzed and redesigned so that the relational aspects can be more readily managed and utilized by interested clients. It is comprehensive in that it will include field descriptions as well as laboratory characterization and information on the map units themselves. This is not part of global change per se but is relevant to the many users who desire soil information.

Facilitated Workshop Session: Global Change

The participants of the workshop were divided into four working groups, one group for each of the four issues, with representation from each of the agencies. The overall charge to this working group was to explore the possibilities for developing interagency cooperation within the Global Change issues. More specifically the working group was to:

1. Determine important **topic areas** that are common to all four agencies, prioritize the topics and develop a rationale explaining why the top 3 to 5 topics are important.

2. Develop a **vision** for the future direction of water resource programs, including identification of research and technology transfer needs and organizational needs and a brief vision statement.

3. Identify and prioritize any major **barriers** to strengthening interagency cooperation.

4. Develop a list of **recommendations** to implement the vision statement and strengthen interagency cooperation.

Each work group was assigned a trained facilitator to assist the group in reaching a consensus and a recorder to document the working groups process and outputs. The outputs of each working group were typed at the end of the day and made available to the working groups the next day and to all participants at the end of the workshop during the wrap-up discussion session. We wish to thank the facilitator's and recorders for outstanding efforts during the workshop.

Lead Facilitator:	**Dave Miller**, Forest Service Information Systems, Washington D.C.
Global Change Facilitator:	**Bill Anthony**, Forest Service, Lakewood, CO.
Recorder:	**William Kustas**, Agricultural Research Service, Beltsville, MD.

Cross Cutting Topics Identified

I There is a lack of understanding of changes in the fluxes of mass and energy caused by global change and their effect on water resources in terrestrial and aquatic ecosystems.

II Understanding of linkages among global, regional and local models and processes must be developed.

III Effective technology transfer of global change research results between researchers and users is needed.

IV Strategies to respond to the direct and indirect effects of global change on water quantity and quality and timing for competing uses need to be developed.

Workshop Output - Global Change

Cross Cutting Topic I

There is a lack of understanding of the changes in the fluxes of mass and energy caused by global change and their effect on water resources in terrestrial and aquatic ecosystems.

Rationale:

There is limited knowledge of the basic processes and feedback mechanisms relating to the fluxes of mass and energy to, within and from terrestrial/aquatic ecosystems. There cannot be effective management and mitigation strategies without knowledge of these basic processes and their effect on water resources. Viable options are needed for examining the effect of different global change scenarios on water and energy fluxes.

Vision Statement:

By the year 2000, USDA's knowledge of processes and mechanisms relating to mass and energy fluxes, will permit adequate evaluation of the effect of different global change scenarios on water resources in terrestrial/aquatic ecosystems.

Research and Technology Needs:

- Measure and model current fluxes of mass and energy to and from atmosphere, streams, lakes, soil and vegetation from selected locations (e.g., climatic regions).
- Understand the feedback mechanisms among temperature, runoff, soil moisture and precipitation.
- Evaluate rate and direction of possible changes in flux components in response to global change.
- Better understanding of behavior of natural water delivery systems at a range of scales.
- Determine impacts of low frequency high magnitude events on water resources.
- Develop methods to transfer information learned from one location to another.

Organizational Needs:

- Improve effectiveness of USDA Global Change Office.
- Increase interagency cooperation and communication.
- Increase scientific freedom to foster interdisciplinary interagency projects.
- Improve agency directors to scientists communication.
- Changes in evaluation of scientists.
- Effective presentation of USDA assets.
- Sufficient number of adequately trained research support personnel.

Barriers:

- Research topics are targeted to specific locations.
- Funding mechanisms do not easily allow pooling and sharing of money among agencies.
- Lack of communication among agencies.
- Evaluation process does not allow scientist to spend enough time for thorough analysis and interpretation or contribute significantly to non-science location/agency maintenance.
- Lack of effective public relations.

Cross Cutting Topic II

Understanding of linkages among global, regional and local models and processes must be developed.

Rationale:

A great deal of research has been conducted to predict changes in climate on a global scale due to increases in greenhouse gases. Fluxes of mass, energy, and water on small areas of the earths surface have also been the subject of a great deal of research. However, it has not been possible to quantitatively link these two processes to predict the effects of global change on a regional scale. An understanding of the linkage between small scale and large scale processes is essential for predicting regional effects.

Vision Statement:

By the 21st century we will make significant progress on understanding of linkages between scales and develop technology/methodology to predict impacts of global changes on water resources at the regional scale.

Research and Technology Transfer Needs:

- Investigate appropriate information, processes, and parameters to pass from one scale to another (time and space scale).
- Develop technology to simulate and measure important parameters at the regional scale (e.g., remote sensing).
- Identify appropriate utility of large scale output from global scale models for input into smaller scale terrestrial/aquatic process models.
- Develop mathematics for scaling.
- Develop techniques for direct measurement and estimate of fluxes of mass and energy at the regional scale.
- Development of a framework for integrating individual models.

Organizational Needs:

- Understand funding mechanism.
- Recruit expertise in atmospheric science, landscape ecology, mathematics, modeling and remote sensing.
- Equipment needs for measuring, monitoring and processing.
- Need to realize holistic approach necessary to deal with global change issues.
- Long term commitment in funding and scientific research required to obtain significant progress.
- National research teams, multidisciplinary, multidepartmental and multiagency approaches are needed.

Barriers:

- Funding.
- Public indifference.
- Short term mind set both in the political and public arena.

Cross Cutting Topic III

Effective technology transfer of global change research results between researchers and users is needed.

Rationale:

Researchers publish their results in the referred literature in a timely manner. The users are not well versed in extracting the research results from the referred literature. As a result, both researchers and users can't fully capitalize on the research results. The researcher is not currently rewarded for making the extra step of developing the management interpretation of the research for the user. All USDA agencies involved in global change research have this problem.

Vision Statement:

Technology will be transferred in a timely manner. Users and scientists are active in the technology development. The technology is understood and implemented by the users.

Research and Technology Transfer Needs:

- To interpret and present complex research data.
- Making better use of long term data sets.

- Need to bridge the gap between research and interpretation.

- Sharing data bases and analyzing the data bases together.

Organizational Needs:

- Need a group in the scientific community to develop presentation methods.

- More interagency assignments - scientists working with managers and vice versa.

- Agencies need to publish compendium of available data and how to obtain it.

- Agencies need to give researchers more credit for technology transfer.

Barriers:

- Too much local option to maintain or not maintain data bases.

- Lack of funding specified for data base maintenance.

- Lack of reward system for technology transfer.

- Lack of awareness of data base existence.

- Lack of knowledge of what research is being done and who's doing it.

Recommendation:

- Agencies expand and utilize exchange programs between management and researchers to improve technology transfer.

Cross Cutting Topic IV

Strategies to respond to the direct and indirect effects of global change on water quantity and quality and timing for competing uses need to be developed.

Current Situation:

Adaptive and mitigative strategies to counteract the negative effects on water resources due to global change do not exist. Therefore, we are currently unprepared to recommend new or revised forest and agricultural practices to land managers that will be necessary due to global change.

Vision Statement:

We will bring currently available agriculture and forest management knowledge together with emerging new information on the direct and indirect effects of global change. This will provide predictive information for managers to maintain or improve present water quantity, quality, and timing in advance of global change.

Research and Technology Transfer Needs:

- Gather relevant body of information about ecosystems and management effects that will be influenced by global change. Identify knowledge gaps which are important to address needed adaption's/mitigation's for management approaches.

- Assessments of the impacts of global change on water resources using integrated models based on improved process knowledge of atmosphere, biosphere and geosphere interactions.

- Study alternative management approaches, technologies to maintain or improve quantity, quality, and timing of water resources.

- Conduct pilot tests of management approaches in operational settings.

Organizational Needs:

- Conduct more research which supports management's needs.

- Develop informational data networking systems among USDA agencies.

- Improve the active, close-working relations among researchers and managers on similar projects within USDA, and among different agencies.

Barriers:

- Few rewards for researchers for projects in operational settings.

- Poor understanding by managers of the need to incorporate latest good science to solve problems.

- Managers don't understand degree of effort, funding, real costs and time to conduct research.

- Need better funding estimates (real costs).

Recommendations:

- Research teams prepare assessments of available water resource information on an appropriate geographic scale to identify gaps and provide meaningful information for mitigation and adaptation. This involves integrated modeling to develop approaches to sustainable water resource conditions.

- Encourage testing and calibrating of adaptation mitigation models on areas with existing long term data.

General Recommendations:

- Develop research team across agency, university and international groups and organizations under the auspices of USDA Global Change Office (e.g. skills file).

- Agencies will have the responsibility in communicating the benefits of global change research to the public. USDA Global Change Office will provide the leadership but will be done by the agencies in numerous ways.

- The agencies should work with OPM to revise scientist evaluation process which recognizes the importance of thorough analysis and technology transfer.

- USDA needs to have collaborative interagency long-term commitment to planning and funding global change research because of critical need for USDA skills and knowledge in global change.

- Develop USDA index to natural resource data bases to include subject matter, location, availability and access methods.

- USDA lead the development of a USDA directory of research scientists and area of expertise and location.

- USDA require agencies to fund and support data base management (computer accessibility).

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